GEOTECHNICAL REPORT

PHASE II STUDY AND
EVALUATION OF
TSAILE DAM, APACHE CO.,
ARIZONA

20 July 1981

ENGINEERS TESTING
LABORATORIES, INC.



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15 February 1980

Attention: Don Conroy
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Job No. 912-1028
Inv. No. 112 1758

Project: Phase II Study and Evaluation
of Tsaile Dam, Apache County, AZ

In accordance with our agreement, this firm has performed a Phase II Study and Evaluation of Tsaile Dam, Apache County, Arizona.

The accompanying report contains the results of the subsurface exploration, laboratory testing, geotechnical analyses, hydrologic and hydraulic analyses, and the conclusions and recommendations derived from our engineeering evaluation. This evaluation has been formulated in accordance with generally accepted professional engineering practices in the field of foundation engineering, soil mechanics, engineering geology, hydrology and hydraulic engineering. The hydrologic and hydraulic evaluation of the spillway adequacy was performed by Hydro-Data, Inc. All of the work was performed in accordance with the Corps of Engineers' "Recommended Guidelines for Safety Inspection of Dams".

It has been a pleasure participating with your agency on this project. Should any questions arise regarding this report, please contact the undersigned.

Respectfully Submitted,

ENGINEERS TESTING LABORATORIES, INC.
Geotechnical Services

By: _____ Reviewed By: _____
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Phase II Study and Evaluation
of Tsaile Dam
Job No. 912-1028

TABLE OF CONTENTS

Table of Contents
List of Figures

SUMMARY

I. INTRODUCTION

A. Scope.....1
B. General Description of the Project.....1

II. HISTORY OF TSAILE LAKE DAM

A. Design and Construction.....2
B. Previous Inspections and Evaluation.....3

III. PHYSIOGRAPHY & TOPOGRAPHY.....4

IV. REGIONAL GEOLOGY

A. Stratigraphy.....5
B. Structure.....5

V. SUBSURFACE EXPLORATION

A. General.....5
B. Sampling.....6
C. Core Drilling.....6
D. Pressure Testing.....7

VI. LABORATORY TESTING

A. General.....7
B. Physical Properties.....8
C. Strength Testing.....8

VII. SITE GEOLOGY

A. General.....8
B. Embankment and Alluvial Overburden.....9
C. Bedrock.....10
D. Groundwater Conditions.....14

VIII. ANALYSIS AND RECOMMENDATIONS

A. Stability Analysis.....14
B. Remedial Construction Work.....15

1. General.....15
2. Abutment Grouting.....16
3. Repair of Eroded Areas at Downstream Toe/Abutment Contacts, Downstream Slope, and Dam Crest.....21
4. Spillway Modifications for Increased Capacity.....22
5. Cost Estimates.....25

C. Alternate Site Considerations.....28
D. Periodic Inspections.....29

References.....31

Figures.....33

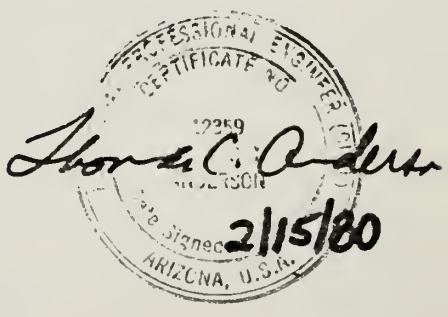
APPENDIX A - Boring Logs, Pressure Test Results, Summary of Pressure Test Results.....39

APPENDIX B - Laboratory Test Results.....71

APPENDIX C - Stability Analysis.....83

APPENDIX D - Proposed Grouting Program and Guide Specifications..87

APPENDIX E - Hydrologic and Hydraulic Evaluation of Spillway Adequacy



FIGURES

Figure 1 Geology Map of Area

Figure 2 Site Plan/Test Boring Location

Figure 3 Geologic Profile A-A'

Figure 4 Plan for Proposed Grouting Program

Figure 5 Plan Showing Eroded Areas at Downstream Toe

Figure 6 Proposed Spillway Modifications - Options 1 and 2

Phase II Study and Evaluation
of Tsaile Dam
Job No. 912-1028

SUMMARY

A Phase II study and evaluation was performed for Tsaile Dam to develop the most effective means of correcting the conditions causing the severe piping erosion observed at the downstream abutment contacts and of modifying the spillway and dam crest to pass the required flood event without overtopping. This study included the performance of ten test borings, undisturbed sampling, rock coring and water pressure testing in those test borings and laboratory testing of the samples recovered. The results of the field and laboratory work were utilized to develop specific recommendations for treatment of the abutment contact areas and to analyze the embankment stability. In addition, refined hydrologic and hydraulic analyses were performed to define the Probable Maximum Flood (PMF) and analyze various spillway and dam crest modifications for passing the 0.5 PMF without overtopping.

From these studies, the following major conclusions and recommendations are presented for the project:

1. The upstream and downstream slopes of the dam have adequate factors of safety for static load conditions.

2. The severe piping erosion at the abutment contact areas is the result of seepage through the fractured and jointed sandstone abutments, presence of poorly placed and compacted fill beneath the abutment overhang areas, and a downstream embankment zone of dispersive clay material. This condition can be corrected by the following remedial measures:

a. Abutment grouting program (Section VIII B.2. and Appendix D) to reduce the seepage within the abutments immediately adjacent to the embankment and to compact the materials within the abutment overhang areas.

b. Repair of the eroded areas (Section VIII B.3.) by placing lean concrete beneath the excavated overhang areas and backfilling the areas with sand filter material to prevent future piping of the dispersive clay materials.

3. The capacity of the spillway can be increased to the required level by either of the following options (Section VIII B.4.):

a. Option 1 - lowering the spillway crest to Elevation 7028.3, increasing the spillway width is 200 feet, while leaving the dam crest at Elevation 7037.

b. Option 2 - leaving the spillway crest at Elevation 7029.6 and width at 107', excavating 50' wide by 3' deep overflow channel immediately north of existing spillway, and raising dam crest to Elevation 7040.

4. After the repairs have been completed, periodic inspections should be made of the dam and downstream abutment contacts by an experienced geotechnical engineer. Any signs of seepage and erosion in the repair areas should be noted and steps taken to identify any necessary further remedial repairs.

Cost estimates for the recommended repairs are provided in Section VIII B.5. of the report.

REPORT

Phase II Study and Evaluation
of Tsaile Dam
Job No. 912-1028

I. INTRODUCTION

A. Scope: A Phase I dam safety inspection was performed by Toups/ECI in 1978. As a result of the Phase I inspection, Tsaile Dam has been considered unsafe due to the advanced condition of piping erosion at the downstream abutment contacts, to the formation of erosion gullies on the downstream slope of the dam and to the inability of the spillway to pass the Probable Maximum Flood (PMF) or even one-half of the PMF without overtopping. It was also noted that the outlet works were inoperable. Immediate repair action was recommended.

The purpose of this current study is to determine the causes of the seepage and piping erosion condition along the downstream abutment contacts, evaluate the stability of the dam and determine the most effective spillway modifications required to increase the capacity to pass the required flood event.

The project included the performance of subsurface exploration, and laboratory testing on the samples recovered. Stability analyses were performed for the existing embankment, along with hydrologic and hydraulic evaluation of the spillway. Cost estimates were developed for the recommended repairs. Preparation of plans and specifications for the remedial work recommended herein is beyond the scope of this project. Also, no consideration has been given to modifications to the control works to render them operable.

B. General Description of the Project: Tsaile Dam is located in Apache County, Arizona, on the Navajo Indian Reservation. The site is located about 1 mile west of Highway 12 approximately 55 miles north of Window Rock, Arizona. The rolled earthfill dam has a crest length of approximately 1950 feet and is approximately 52 feet high at the maximum cross

section. The zoned embankment has a central core of "fat" clay with a cutoff trench located slightly upstream from the centerline of the dam. The upstream and downstream zones are composed of a mixture of clay and sand with approximate slopes of 3:1 (horizontal to vertical). A 107 foot wide concrete ogee shaped spillway is located in the north abutment and has a crest elevation approximately 7.4 feet below the top of the dam (Elevation 7037 feet, mean sea level datum).

II. HISTORY OF TSAILE DAM

A. Design and Construction: Tsaile Dam was constructed by the Navajo Tribe in 1963. The design firm for the dam was Chambers and Campbell Inc. of Albuquerque, New Mexico. It is our understanding that the site of the present dam was moved 200 to 300 feet upstream from the original dam location where test borings were made. This location change was necessitated by extensive fracturing of the bedrock during blasting operations of the rock foundation. Although the dam site was shifted upstream, no further exploration was undertaken.

According to Mr. Eugene Budiselick, the BIA representative at the site during construction, no drawings or specifications for construction of the relocated dam were available. The four sheet set of drawings for the Tsaile Reservoir by Chambers and Campbell, Inc. dated July 5, 1963 were prepared at the site as construction proceeded. These drawings therefore represent "as-built" construction plans. Conversations with Mr. Budiselick, along with photographs taken during construction indicate that these drawings are accurate. It should be noted that these drawings used an assumed elevation which is approximately 7 feet lower than the actual elevation.

Conversations with the BIA representative during the original dam construction indicates that all of the sandstone removal for the existing spillway channel was accomplished by ripping with a D8 or D9 Cat.

No grouting or foundation treatment was undertaken for either abutment. Beneath the abutment overhang areas, an attempt was made to push material into the areas below the overhangs, rather than removing the overhangs and sloping the rock abutments to allow for proper compaction. Minor seepage was observed shortly after construction in the downstream toe areas at the following locations:

a. Downstream toe in the stream channel section near the outlet pipe,

b. fractured rock abutments downstream from the dam as noted by wet and mossy vegetation growth,

c. and at the downstream toe/abutment contacts.

B. Previous Inspections and Evaluations: On October 11, 1967, an inspection of Tsaile Dam was performed by Mr. Tom Isaacson of Chambers and Campbell, Inc. He noted seepage was still present along the south abutment rock at about 3 gallons per minute (estimated). The sandstone comprising the south canyon wall was noted to be saturated for 200 feet downstream from the toe and to be sweating. In addition, Mr. Isaacson noted that the temperature of the water exiting from the south abutment was relatively warm and he indicated that the water may be entering through the exposed sandstone abutment on the south end of the dam. Seepage along the north abutment rock and previous sand boils at the downstream toe had stopped. The total concentrated flow from all seepage was estimated to be 5

gallons per minute. Erosion of the fill had not increased since he last visited the dam in August 1965. During the same inspection visit, Mr. Isaacson indicated that a considerable amount of water was seeping under the spillway crest near the south end.

On October 18, 1977, engineers from the Department of Health, Education and Welfare noted seepage and piping erosion along the south abutment of the dam near its base.

A Phase I dam safety inspection was performed by Toups/ECI on July 29th and 31st, 1978. The results are contained in the Phase I Inspection Report dated December 1978 and have been briefly summarized in Section I.A. of this report.

III. PHYSIOGRAPHY AND TOPOGRAPHY

The Tsaile Lake area is located in northeastern Arizona within the Colorado Plateau Physiographic Province. Structurally, the area is on the Defiance Plateau at the base of the Chuska Mountains. The area is characterized by nearly horizontal sedimentary rock, consisting primarily of sandstone.

The dam site is situated at the head of Canyon Del Meurto of Canyon De Chelly National Monument. The canyon varies in width from about 100 feet at the dam to close to 200 feet downstream. The valley floor has a flat bottom and is covered by alluvial material, while the walls are nearly vertical and composed of sandstone.

IV. REGIONAL GEOLOGY

Figure 1 is a geologic map of the area on which the dam site has been indicated.

A. Stratigraphy: The oldest exposed rocks in the immediate vicinity of the dam are those of the Chinle Formation. The Chinle Formation is locally composed of the lowermost Shinarump Member and the upper Monitor Butte and Petrified Forest Members.

The lower Shinarump Member consists of a light gray to yellowish gray sandstone and conglomerate and is overlain by the Monitor Butte Member which is composed of siltstone, sandstone and lime-pellet conglomerate. The Petrified Forest Member overlies the Monitor Butte Member and is composed of claystone, siltstone and minor amounts of sandstone. Near the dam site, the contact between the Shinarump and Monitor Butte Members is at approximately Elevation 7050±, while the contact between the Monitor Butte and Petrified Forest Members is at about Elevation 7060±.

B. Structure: The Tsaile Lake area is underlain by nearly flatlying strata, with a regional dip of 2 to 3 degress toward the northeast. As shown in Figure 1, there is a north-south trending anticline (Defiance Anticline) located about 4 miles to the west of the dam. Two roughly parallel northeast-southwest trending faults have been identified (see Figure 1) just south of the dam site. These faults form what is known as the "Tsaile Graben". However, there are no indications that these are active faults.

V. SUBSURFACE EXPLORATION

A. General: Subsurface exploration for analysis of the embankment adequacy and seepage conditions was accomplished by disturbed and undisturbed sampling of the embankment fill and alluvial overburden and core drilling of the bedrock. A total of 10 borings were drilled for a total footage of 512.3 lineal feet. All borings were advanced to the top of rock and

maintained open by means of 7 inch OD hollow stem augers. The boring logs are presented in Appendix A, and the locations of all borings are shown on the Site Plan (Figure 2).

B. Sampling: Undisturbed and disturbed samples were obtained within the various borings. Samples of the auger cuttings were obtained in all of the borings as an indication of the nature of the embankment materials. The Standard Penetration Test method was utilized to obtain disturbed samples in Boring 4 at the base of the embankment zone at the rock contact and also in Borings 6 and 9 within the cored portions of the holes. The Standard Penetration Test Value (N) gives an indication of the in-situ relative density of non-cohesive soils and a very approximate estimate of the consistency of cohesive soils. Results of Standard Penetration Tests are shown on the respective boring logs.

A number of relatively undisturbed samples of the embankment and underlying alluvial materials were obtained in Borings 1, 3 and 5, with a ring sampler and/or 3 inch diameter shelby tubes. In these borings, the undisturbed samples were generally obtained at alternating 5 foot vertical intervals. This sampling procedure is in accordance with ASTM: D1587. The various sampling methods are described in Appendix A.

All samples were sealed immediately in the field and returned to our laboratory for further classification and testing.

C. Core Drilling: All of the borings, with the exception of Boring 8, were cored for lengths of 5 to 25 feet in order to evaluate the rock conditions within the abutment and foundation areas. Coring was performed utilizing a NX standard rotary double tube core barrel with bottom discharge diamond bits. Outside of the abutment overhang areas, core recovery ranged

from 78 to 100%, while the rock quality designation (RQD) values were in the range of 13 to 83%. Within the abutment overhang areas, the core recoveries were considerably lower, 3 to 47%, while the RQD values ranged from 0 to 22%.

Boring 8, north of the existing spillway, was drilled with a rock bit to a depth of 14 feet below the existing grade to determine the surface level and nature of the rock in this area.

D. Pressure Testing: To evaluate the permeability and seepage potentials within the rock abutments and overhang areas, bore hole packer tests were performed in all of the borings, with the exception of Boring 3 and 8. The test intervals varied from 10 to 20 feet and a single packer was utilized at the top of the test interval. Clean water was pumped under pressure to the isolated test interval below the packer level. The flow rate was measured with a flow meter, while the pressure, which ranged from 5 to 30 psi, was monitored with a pressure guage.

The results of individual packer tests are contained in Appendix A with the individual boring logs. Also included in Appendix A is a summary of the pressure test results and the computed permeability for the assumed length of the test intervals.

VI. LABORATORY TESTING

A. General: Laboratory testing was performed on representative samples of the embankment and foundation materials. Index testing was performed on disturbed and undisturbed samples to define the physical properties, whereas undisturbed samples were used to determine the shear strength parameters of the embankment soils. The results of all laboratory tests are contained in Appendix B.

B. Physical Properties: Water content and dry density determinations were made on all of the undisturbed samples. A total of 11 Atterberg tests and Minus #200 Sieve Determinations were performed on samples of the embankment materials and surface soils (Boring No. 8) along with one grain size analysis of the alluvial material recovered from Boring 3. Two moisture density tests were performed on the cuttings recovered from Boring 3 and surface samples obtained from the downstream slope to determine the maximum density for the embankment materials.

The dispersive potential of the fine grained materials was assessed by 4 pinhole dispersion tests (reference 7) performed on representative samples of the cohesive embankment materials from the downstream slope area (Figure 2). Results of these tests indicate that the low plasticity sandy clay and clayey sand soils comprising the downstream embankment zone are somewhat dispersive (D2 or D2/ND4), while the higher plasticity silty clay soils are nondispersive (classified ND1 and ND2).

C. Strength Testing: Nine (9) unconfined compression tests were performed on undisturbed 3 inch diameter shelby tube samples of the embankment materials from Borings 1, 3, and 5. The unconfined compressive strength of these undisturbed samples was estimated through the use of the pocket penetrometer. Results of the pocket penetrometer and laboratory tests are included in Appendix B.

VII. SITE GEOLOGY

A. General: At the site, the valley floor is approximately 100 to 200 feet wide with an elevation in the range of 6986 to 6988 feet. The rock abutments rise on a very steep to nearly vertical slope to approximately Elevation 7000, while the slope above this level is moderately steep to Elevation 7040 and

above. At the level of the valley floor, overhang areas (with overall heights of 5 to 7 feet) are present below the nearly vertical portion of the rock abutment areas. The lower 4 to 6 feet of these overhang areas are filled with alluvium. Geologic profile A-A', along a longitudinal center line of the dam at the maximum section, is presented in Figure 3.

B. Embankment and Alluvial Overburden: The borings along the crest of the dam indicate that the embankment has a central core of silty clay of medium to high plasticity. The top of the central clay core is at a depth of approximately 7 to 8 feet below the crest and the core material extends to the level of the underlying alluvial material comprising the valley floor. The borings along the dam center line did not penetrate the cutoff trench area.

The borings performed along the dam crest and samples taken from the downstream slope indicate that the upstream and downstream zones are composed of sandy clay to clayey sand material of low plasticity. Thus, the design drawings are apparently accurate in terms of the embankment cross section. All of the embankment materials are reddish brown in color and are stiff to very stiff in consistency. Table B-1, Appendix B, contains the measured densities from the undisturbed ring samples and 3 inch shelby tube samples along with the maximum density as determined by ASTM D698 laboratory tests. The computed percent compaction predominantly ranges from 95 to 100 percent (actual range: 88 to 100+), which indicates that the embankment materials were properly compacted. The moisture contents for most of the materials are well above the optimum moisture content.

Borings 2, 4, 6 and 7, which penetrated the abutment overhang areas, indicate a thin zone (1 to 2 feet) of soft clay fill beneath the overhang and underlain by alluvial materials. The pressure tests within the overhang zone indicate relatively high water takes, 20 to 30 gallons per minute at pressure levels of 10 to 15 psi. These pressure tests, along with the fact that all drill water within the core was lost upon encountering the overhang zone, indicates the portions of the embankment beneath the overhangs are poorly compacted and quite permeable. This verifies the earlier statement that the embankment materials were only pushed beneath the overhang areas during construction.

A test pit, excavated just downstream from the dam along the south abutment, revealed that the overhang extended back a distance approximately one and one-half feet beyond the nearly vertical face.

The valley floor alluvial material(5 to 7 feet) consists predominantely of sand with varying amounts of silt, clay, and gravel.

C. Bedrock: Beneath the valley floor alluvium and the dam abutments, the bedrock consists of gray and slightly brown, fine grained sandstone (Shinarump Member of the Chinle Formation) which is thinly bedded, moderately fractured to very fractured and slightly weathered. Below approximately Elevation 6980, the grain size of the sandstone increases, and coal particles and stringers are present.

A detailed geologic reconnaissance was performed of the north abutment area just downstream from the dam and the south abutment area, both upstream and downstream from the embankment. The sandstone exposures are thinly bedded with

bedding thicknesses ranging from 3 inches to 4 feet, but predominantely in the range of 6 inches to 1 1/2 feet. The sandstone shows cross stratification, although not prominant in some of the exposures. Lack of definition of the cross stratification gives the sandstone a horizontally bedded to somewhat massive appearance.

Bedding plane fractures, due to stress relief, are very common throughout the sandstone exposures. These fractures are often filled with clayey material (1/32 to 1/8 inch in thickness). The predominant direction of joint sets in the Tsaile area is northeast to southwest, which reflects the general trend in the structural features in the Defiance Plateau. Joints are nearly vertical. Major joints are present which control the topography of the rock abutments to a certain extent. Spacing between the major joints varies between 10 to 50 feet. Numerous minor joints are also present and reflect the same northeast to southwest trend. The minor joints are open with widths of 1/32 to 1/8 of an inch, while the major joints show considerable openness, especially near the vertical valley walls (6 inches to 12 inches wide at the surface but probably decreasing with depth into the rock).

The following is a summary of the observation and measurements for the south and north abutment areas:

North Abutment - Immediately downstream from the dam.

Bedding - Strike varies from N5° W to 25° W, while dip varies from 6 to 10° E.

Jointing - Joint sets are present with predominant directions varying from N 65° to 80° E to N 30° to 50° E, with nearly vertical dips (70 to 90°), joint spacing is 2 to 3 feet, and joints open 1/16 to 1/4 inch at the surface.

South Abutment - Immediately downstream from dam.

Bedding - Strike varies from N 20° E to N 12° to 17° W, while dip varies from 6 to 10° E.

Jointing - Direction varies from N 70° to 75° E to N 3° W, dip nearly vertical (70 to 90°), and joint sets open 3 inches to 12 inches at valley wall.

South Abutment - Upstream from dam in reservoir area (southeast of station 19+90 to 20+00).

Bedding - Strike N 2° to 12° E, dip 2° to 6° E.

Jointing - Major joints - direction varies from N 52° to 79° E, dip nearly vertical (70° to 90°), joint spacing 5 to 15 feet and joints open 1/8 to 1 inch at surface. Minor joints - Direction varies from N 23° W to N 31° E, dip nearly vertical (70° to 90°), joint spacing 2 feet to 10 feet, and joints open 1/32 to 1/4 inch at surface.

The above indicated upstream portion of the south abutment area is the most likely entrance point for seepage into the south abutment.

Results of the borings and pressure tests in the north abutment outside of the overhang area indicate that the sandstone is of fair to good quality and of relatively low permeability. The south abutment is of very poor to fair quality rock, as indicated by the RQD values, and has a much higher permeability than the north abutment. A zone of sandy clay/clayey sand with sandstone fragments and gravels was encountered between Elevation 6990 and 6980 in Boring 9. Standard Penetration Tests performed within this zone indicate that the material is relatively soft, while the pressure test indicates relatively high permeability, similar to the overhang zone area. This zone possibly represents a highly fractured, interbedded claystone and sandstone zone which has undergone extensive weathering. The color of material within the zone was reddish brown, similar to the thin clay seams encountered in the sandstone formation in Borings 2 and 4 immediately above the level of the overhang. The presence of this zone within the sandstone formation would explain the overhang formation, due to differential weathering of the zone leading to undercutting of the more competent overlying sandstone.

Siltstone interbedded with claystone and sandstone was encountered in Boring 4 below Elevation 6972 and in Boring 5 below Elevation 6986. This represents another anomaly within the sandstone formation. The presence of the interbedded siltstone, the zone of clayey material between Elevations 6980 and 6990 in Boring 9, and variation in measured bedding plane dips from the overall regional dip suggests that the two known faults to the south of the dam site could have had a definite influence on the rock conditions within the south abutment area.

Boring 8, approximately 100 feet north of the existing spillway crest, indicates that the surface of the sandstone formation is at a depth of approximately 3 feet below the existing grade. Surface soils consisting of sandy silt to silty sand were encountered overlying the bedrock. These soils probably represent wind blown or residual soil deposits. Sandstone similar in nature to that encountered in the dam borings was encountered between the 3 foot and 14 foot depth intervals.

D. Groundwater Conditions: Groundwater level measurements recorded during and after completion of the borings are shown on the respective borings logs and also on Figure 3. These readings indicate that the groundwater level at the time of exploration was situated at Elevation 6992 to 6998 within the abutment areas, while the groundwater level within the stream channel was situated at approximately Elevation 6988. It should be noted that the reservoir was virtually empty at the time the field exploration was performed. Fluctuations in the location of the long-term groundwater level should be anticipated depending on variations in precipitation, evaporation, surface runoff and the reservoir level.

VIII. ANALYSIS AND RECOMMENDATIONS

A. Stability Analysis: Utilizing the undrained shear strength from the unconfined compression tests, a simplified stability analyses was performed for the upstream and downstream slopes utilizing slope stability charts (reference 5). The analysis was performed for the maximum embankment section near station 16+15 and the results are contained in Appendix C. Acceptable factors of safety were computed for the upstream slope for the conditions of normal pool and sudden drawdown from normal to minimum pool. Acceptable factors of safety were also computed for the downstream slope.

The dam is located in seismic zone 2; thus a seismic acceleration of 0.05g is recommended for design. Experience indicates that application of a horizontal force due to an acceleration of 0.05g to the static stability analysis should result in a reduction in the computed factors of safety on the order of 10 to 15 percent. The resulting factors of safety would still be adequate for the earthquake loading condition.

B. Remedial Construction Work

1. General: Several aspects of Tsaile Dam are inadequate and need repairs and modifications. The spillway has been shown by the Phase I report to be undersized. The piping and erosion conditions at the downstream abutment contacts need to be repaired, along with the erosion channels in the downstream slope. As a result of the present subsurface exploration work at the site, it appears that the piping and erosion conditions are the result of the following factors:

   a. Seepage through the fractured and jointed sandstone abutments.
   b. Presence of the abutment overhang zones which were improperly treated and backfilled.
   c. Presence of dispersive clay soils in the downstream embankment zone.

   A combination of these three factors is believed to have caused the severe piping and erosion conditions observed at both of the downstream toe/abutment contact areas. Another minor factor which may have contributed to the development of these conditions and also the erosion channels which have formed in the downstream slope is transverse cracking of the embankment due to differential settlement caused by the abrupt change in embankment height at the nearly vertical abutments.

The following report sections indicate in detail the recommended remedial construction work for the dam and spillway, which should be undertaken with the reservoir empty. In addition, cost estimates are provided for the various recommended repairs and modifications. The recommended remedial work should be accomplished under the observation and testing directed by an experienced soils engineer or a representative of the owner.

2. Abutment Grouting: To minimize the seepage within the abutments adjacent to the embankment zone, it will be necessary to undertake a program of abutment grouting. Only the rock abutment areas adjacent to the dam need to be treated. However, this suggested program will not eliminate all abutment seepage; therefore, the abutment seepage exiting downstream from the dam should be expected to continue, although substantially reduced.

A line of grout holes (combination compaction and curtain grouting) is recommended along each abutment contact area. A five foot horizontal spacing is recommended for these grout holes. The estimated total number of holes along each contact abutment is 31 with an average depth of 40 feet. It is anticipated that the zone between Elevation 6995 to 7000 and Elevation 6980 will require grouting, approximately 15 to 20 feet in each grout hole. The overhang zone will require compaction grouting in order to densify the soft clay fill. The fractured sandstone formation will require curtain grouting to seal the fractures and joints to reduce the seepage against the adjacent embankment materials. A line of curtain grout holes is recommended extending along the longitudinal centerline of the dam away from each abutment contact for a

distance of approximately 100 feet. The recommended curtain grout hole spacing is 10 foot on center for the south abutment and 10 to 20 foot on center for the north abutment. These curtain grout holes are expected to have an average depth of 60 feet with a grouted zone from approximately Elevation 7000 to 6980 or an average grouted length of approximately 20 feet per grout hole.

For all grout holes, it is recommended that alternate holes be performed initially. Once these alternate holes are completed, the intermediate holes should be grouted. Where high grout takes occur within the secondary phase of the grouting operations, additional holes may be necessary and should be performed by the split-spacing method.

Figure 4 presents the plan for the recommended grouting program. Comments on the grouting program along with estimates for the drilling footage and grout takes are provided in Appendix D. Guide specifications for the grouting contract are also included in Appendix D.

All grout holes, which penetrate the existing embankment, should be cased to the top of rock. The stage grouting method is recommended for grouting of the rock and the maximum stage interval should be 5 feet. Each stage should be drilled and washed. A packer should be set within the bottom of the casing and the stage pressure tested with water. If the water pressure testing indicates a water take of more than one gallon in five minutes under a pressure of 20 psi, the stage should be grouted until the grout take is less than 1.0 cubic feet in ten minutes. After the grout has attained the initial set, the hole should be

cleaned or redrilled and the sequence of operations repeated at the next lower stage until the hole has been extended to Elevation 6980.

Pervious and loose material in open fractures and foundation rocks should be washed out whenever possible. Each hole should be cleaned thoroughly before grouting with water. Water should be pumped under moderate pressure to clean the clayey seams, to locate surface leaks to be plugged and to test for rate of flow and determination of whether the zone should be grouted. The optimum rate of grout injection is that which permits the largest quantity of cement to be forced into the foundation rock without causing appreciable displacement of the surface. Mix and grouting pressure should be controlled to achieve this purpose. When thin grout mix (10 to 1, water to cement mix) can be pumped readily without developing the maximum permissible pressures, the quantity of cement being injected can be increased by decreasing the water-cement ratio and maintaining the resulting higher pressures. Grout that is too thick may only partially fill the rock fractures; grout that is too thin may shrink when it sets, unless the pressure is sufficient to force the excess water out of the mixture into the surrounding rock. The optimum grout mix, therefore, is one that contains minimum volume of water necessary to carry the cement into all rock voids and fractures.

Determinations of pressures used in grouting operations requires considerable judgement and depends upon the nature of local conditions. When grout pressures exceeds certain critical limits, the possibility exists that foundation rocks may be dislocated, channel ways

of circulation that did not exist previously maybe created. Care should be taken in maintaining low grout pressures for grout holes intersecting channel ways in the sides of the rock abutment area. It is recommended that the pressure in an initially thin grout mix be increased to a level which establishes a free circulation (assuming that channel ways for circulation are present) but not in excess of a grout pressure at the top of the hole equivalent to 1 psi per foot depth above the packer level. Although the hydrostatic pressure of the grout column increases with depth, this pressure is to be ignored in following the maximum pressure rule. As the grout mixtures thicken and as the grout take approaches refusal, pressures maybe gradually increased but should not be allowed to exceed a pressure at the collar of the grout hole twice the equivalent pressure of 1 psi per foot depth of grout hole above the level of the packer.

Some experimention with grout mixes will be necessary during the initial stages of the grouting to determine the optimum conditions for circulation. Beneath the abutment overhang areas, where compaction grouting has been recommended, initially thick grout mixes should be used and sand should be added to the grout mix as an inexpensive filler.

During the water pressure testing and/or the grouting operations, surface leaks may develop which should be caulked or otherwise sealed to promote confined subsurface movement of the grout. If the leaks are inaccessible or cannot be caulked, it may be possible to seal them by manipulating the grout pressure. Leaks probably can be stopped by grouting, beginning with a

5:1 to 3:1 mix and thickening to 1:1 or thicker mix. Where severe leakage or displacement of the foundation rock occurs, it may not be possible to complete the grouting at the maximum pressure. The best procedure in such cases may be to inject thick grout into the hole at reduced pressure and to seal off the hole with thick grout oozing from the leaking rock.

A quick drop in pressure would probably indicate that grout suddenly has forced its way into new channelways of easier circulation. When this happens, grout pressure should be reduced and continued at the lower level to maintain circulation. However, premature thickening of grout or reduction in pressures to hasten grout refusal should be avoided unless it can be demonstrated that grout is escaping the surface remote from the foundation area. So long as grout is circulating somewhere in the dam foundation or in near proximity, it should be assumed to be beneficial to reducing rock permeability and water seepage.

We strongly recommend that a grouting specialist contractor be hired to perform the above indicated grouting program. For this work, we suggest one of the following companies be contacted, all of which have experience in Arizona:

1. The Prepakt Concrete Company
   861 S. Center Street
   Mesa, Arizona 85202

2. Pressure Grout Company
   125 South Linden Avenue
   San Francisco, CA

3. De Val, Inc.
P. O. Box 23594
Portland, Oregon 97223

We suggest that a negotiated time and material type of contract be set-up since it is virtually impossible to estimate in advance the grout hole drilling footage and grout quantities. Accurate records should be maintained during grouting operations as indicated in the guide specifications in Appendix D.

For the line of grout holes along the abutments contacts, it will be necessary to bench into the slope to create approximately 10 foot wide pads in order to accomplish the grouting at 5 foot horizontal spacings. It is anticipated that the Navajo Tribe would probably supply the necessary construction equipment to create these benches for the grouting contractor.

3. Repair of Eroded Areas At Downstream Toe/Abutment Contacts, Downstream Slope and Dam Crest: It is recommended that all loose and disturbed material be removed from the eroded areas shown on Figure 5. After all loose material, vegetation, etc. are removed and a minimum 2 foot deep keyway trench excavated beneath the abutment overhang areas, these zones should be filled with a lean concrete mix having a 6 inch slump and minimum strength of 500 psi. Wood forming will be required to confine the lean concrete beneath the overhang zones. After placement of the lean concrete, it is recommended that the excavated areas be backfilled with a sand filter material, ASTM Specification C33-74a concrete sand, which should control piping and seal leaks through the dispersive

clay within the downstream embankment zone. The sand filter material should be placed in maximum 8 inch lifts and compacted to a minimum of 95% of the maximum density by ASTM: D698. Small construction equipment will be necessary for these operations.

To eliminate the development of future erosion gullies on the downstream slope, it will be necessary to reverse the slope of the dam crest, which is presently toward the downstream slope. It is recommended that the dam crest be regraded and a minimum 6 inch thickness of gravel road base material be added to create a minimum 2% slope toward the upstream face. This will ensure that surface runoff will be toward the reservoir and not the downstream slope. The road base will serve to prevent rutting of the dam crest during rainy periods. The downstream slope should be regraded with a dozer to create a uniform 3:1 (horizontal to vertical) slope or flatter. The existing erosion gullies on the downstream slope should be filled during the regrading operations with the existing slope materials. Compaction of the fill material within the erosion gullies should be by the passage of the dozer tracks.

4. Spillway Modifications for Increased Capacity: The Phase I report indicated a Spillway Design Flood (SDF), equivalent to half the Probable Maximum Flood (0.5 PMF), of 25,379 cfs would result in the (existing) dam crest being overtopped for the existing spillway cross section. A refined hydrologic and hydraulic evaluation, performed as part of the current study, indicates the 0.5 PMF equivalent to 22,400 cfs and the existing dam crest would be overtopped by 1.55 feet for the present spillway configuration. This hydrologic and hydraulic evaluation is contained in Appendix E.

Several analyses were made routing the design flood through modified configurations for the spillway and dam crest, utilizing a combination of widening of the spillway, lowering the spillway crest and raising the dam crest. Results of these analyses are included in Appendix E. The following two options (Figure 6) are feasible for increasing the spillway capacity to pass the required flood event without overtopping the dam crest:

1. Lowering the spillway crest 1.3 feet to Elevation 7028.3, widening the spillway to 200 feet, and maintaining the existing dam crest at Elevation 7037.

2. Raising the dam crest to Elevation 7040, maintaining the existing spillway crest at Elevation 7029.6 and width at 107 feet and constructing a 3 foot deep overflow channel having a width of 50 feet immediately adjacent to the north side of the existing spillway.

Option 1 will involve the greatest expense and the undesirable feature of lowering the normal storage pool 1.3 feet. This option will require removal of approximately 10,000 cubic yards of soil and 16,000 cubic yards of rock for the required increase in spillway width and crest lowering. The rock excavation is expected to require ripping but no blasting. However, all of the excavated material will have to be disposed of on-site, probably by dumping within the reservoir area. For the new spillway crest, a single ogee crest anchored with grouted rebars in the rock is recommended similar to that shown on sheet 3 of the

design drawings (see Phase I report). The existing south spillway wing wall will have to be underpinned due to the lower spillway crest elevation or a new wing wall constructed.

Option 2 will involve a balanced excavation for the overflow channel and fill required for raising the dam crest. Most of the excavated material is expected to be sandy silt/silty sand with a minimum rock excavation (less than 1,000 cubic yards). Material for raising the crest should be placed in 8 inch loose lifts with each lift compacted to 95% of the maximum density by ASTM: D698. The side slopes for the raised crest zone between Elevation 7037 and 7040 should be 1 1/2:1 (horizontal to vertical) or flatter and the final minimum crest width should be 12 feet. A 2 foot (horizontal thickness) zone of rock fill should be placed on the upstream slope to serve as rip rap. The ripped sandstone from the overflow channel should work well for this purpose. The existing double ogee crest can be left in tact. However, it is recommended that the deteriorated surface or spalled concrete areas be repaired by first cleaning with compressed air and applying an epoxy or mortar treatment. The corrugated metal pipe(s) (CMP) beneath the ogee section should be cleaned and debris racks installed over the top of each with a 2 to 3 inch square bar grid. The few isolated areas at the downstream edge of the ogee structure which have been slightly undermined due to scour, should be cleaned and widened as necessary and filled with concrete.

With either option, it is recommended that a zone of wire enclosed rip rap (3 foot thickness) be extended around the end of the dam to protect the embankment from erosion during extreme spillway flows. The ripped sandstone from the spillway or overflow channel excavations should make excellent material for this use.

5. Cost Estimates:

Item	Estimated Cost
a. Abutment Grouting - according to proposed plans and specifications contained in Appendix D (it is assumed that the Navajo Tribe would provide equipment and operator to construct pads in downstream slope for grouting contractor).	$140,000.00-$220,000.00
b. Repair of Eroded Areas at Downstream Toe/Abutment Contacts and Regrading Downstream Slope - Excavating and disposing of disturbed materials from eroded areas shown on Figure 5 and backfilling with sand filter material, such as ASTM specification C33-74A concrete sand, in 8 inch loose lifts. Each lift to be compacted to minimum of 95% of maximum density by ASTM: D698. 400 cu. yds. @ $40.00/cu. yd.	$ 16,000.00

Regarding downstream slope and filling existing erosion gullies. D8 cat and operator 20 hrs. @ $100.00/hr.	$ 2,000.00
Subtotal	$ 18,000.00

c. Spillway and Dam Crest Modifications for Increased Capacity:

Option 1

Soil excavation, hauling and dumping in reservoir area (1/2 mile distance) 10,000 cu. yds. @ $3.70/cu. yd.	$ 37,000.00
Rock excavation by ripping, hauling and dumping in reservoir area (1/2 mile distance) 16,300 cu. yds. @ $4.50/cu. yd.	$ 73,350.00
Removal of existing double spillway crest (107' long) and contruction of new 2'-8" high by 5'-6" wide by 200' long reinforced concrete ogee crest with 5' long grouted rebars into underlying rock at 10' o.c. 85 cu. yds. @ $290.00/cu. yd.	$ 24,650.00
Regrading, placement and compaction of 6" thick gravel road base (imported) on dam crest. 675 cu. yds. @ $24.00/cu. yd.	$ 16,200.00

Extension of wire closed rip rap around spillway end of dam	
60 cu. yds. @ $47.50/cu. yd.	$ 2,850.00
Subtotal	$154,050.00

Option 2

Soil excavation, hauling and placement and compaction of material in lifts on dam crest.	
2,500 cu. yds. @ $1.20/cu. yd	$ 3,000.00
Rock excavation by ripping, hauling and placement in 1.5' wide by 3' high rip rap zone along upstream edge of dam crest.	
500 cu. yds. @ $37.00/cu. yd.	$ 18,500.00
Placement and compaction of 6" thick gravel road base (imported) on dam crest.	
450 cu. yds. @ $24.00/cu. yd.	$ 10,800.00
Repairing deteriorated surface concrete areas of existing double ogee crest with mortar or epoxy treatment, filling small undermined areas at downstream edge of existing spillway crest with concrete, and installing debris racks (24" dia.) over top of existing CMP outlets.	
Lump sum	$ 10,000.00

Extension of wire enclosed rip rap around spillway end of dam. 60 cu. yds. @ $47.50/cu. yd.	$ 2,850.00
Subtotal	$ 45,150.00

d. Development of Plan Drawings and Construction Specifications $ 10,000.00

The above cost estimates are approximate and should only be expected to be accurate to ±20 percent. The cost of construction staking and inspection services have not been included in these estimates.

C. Alternate Site Considerations: Consideration was given to an alternate dam site downstream from the existing site. A cursory inspection was made of the canyon for a distance of approximately 1/2 mile downstream from the present dam. The most feasible dam site appears to be approximately 1500 feet downstream from the existing dam, where the canyon has a top width of approximately 200 to 300 feet and is roughly 75 feet deep. However, this site is undoubtedly on the Canyon DeChelly National Monument property and thus would require a permit to construct a new dam.

To construct the new dam within the canyon, it would be necessary to divert the flow of water within Tsaile Creek and remove all of the existing talus and debris from both sides of the canyon. At the indicated location, a dam approximately 75 feet high by roughly 250 feet long with 3:1 side slopes is probably required. Since the abutments would be jointed and fractured sandstone similar to the existing location, it would be necessary to undertake an extensive grouting program to seal the abutments. A keyway trench would have to be excavated through the alluvium and into the underlying bedrock in the

bottom of the canyon. It would also be necessary to excavate a keyway for a central clay core into the canyon walls, which would require very careful controlled blasting. The spillway location and excavation would be another problem. Approximately 200,000 cubic yards would be required for the new dam at an estimated cost of in excess of $5 million dollars.

D. Periodic Inspections: We strongly recommend that a program of periodic inspections be set-up for several years after the repairs have been completed. The periodic inspections should be undertaken by an experienced geotechnical engineer familiar with the Phase I report and the current study. The inpections should be made at 6 months, 1 year and yearly thereafter. Particular attention should be paid during these inspections to the condition of the downstream slope and the downstream toe and abutment contacts. Any signs of seepage and erosion within these areas should be noted and steps taken to identify any additional problems requiring repair work.

DEFINITION OF TERMINOLOGY

ALLOWABLE SOIL BEARING CAPACITY ALLOWABLE FOUNDATION PRESSURE	The recommended maximum contact stress developed at the interface of the foundation element and the supporting material.
BACKFILL	A specified material placed and compacted in a confined area.
BASE COURSE	A layer of specified material placed on a subgrade or subbase.
BASE COURSE GRADE	Top of base course.
BENCH	A horizontal surface in a sloped deposit.
CAISSON	A concrete foundation element cast in a circular excavation which may have an enlarged base. Sometimes referred to as a cast-in-place pier.
CONCRETE SLABS-ON-GRADE	A concrete surface layer cast directly upon a base, subbase or subgrade.
CRUSHED ROCK BASE COURSE	A base course composed of crushed rock of a specified gradation.
DIFFERENTIAL SETTLEMENT	Unequal settlement between or within foundation elements of a structure.
ENGINEERED FILL	Specified material placed and compacted to specified density and/or moisture conditions under observation of a representative of a soil engineer.
EXISTING FILL	Materials deposited through the action of man prior to exploration of the site.
EXISTING GRADE	The ground surface at the time of field exploration.
EXPANSIVE POTENTIAL	The potential of a soil to expand (increase in volume) due to the absorption of moisture.
FILL	Materials deposited by the action of man.
FINISHED GRADE	The final grade created as a part of the project.
GRAVEL BASE COURSE	A base course composed of naturally occurring gravel with a specified gradation.
HEAVE	Upward movement.
NATIVE GRADE	The naturally occurring ground surface.
NATIVE SOIL	Naturally occurring on-site soil.
ROCK	A natural aggregate of mineral grains connected by strong and permanent cohesive forces. Usually requires drilling, wedging, blasting or other methods of extraordinary force for excavation.
SAND AND GRAVEL BASE	A base course of sand and gravel of a specified gradation.
SAND BASE COURSE	A base course composed primarily of sand of a specified gradation.
SCARIFY	To mechanically loosen soil or break down existing soil structure.
SETTLEMENT	Downward movement.
SOIL	Any unconsolidated material composed of discrete solid particles, derived from the physical and/or chemical disintegration of vegetable or mineral matter, which can be separated by gentle mechanical means such as agitation in water.
STRIP	To remove from present location.

Continued on Reverse Side

SUBBASE	A layer of specified material placed to form a layer between the subgrade and base concrete.
SUBBASE GRADE	Top of subbase.
SUBGRADE	Prepared native soil surface.

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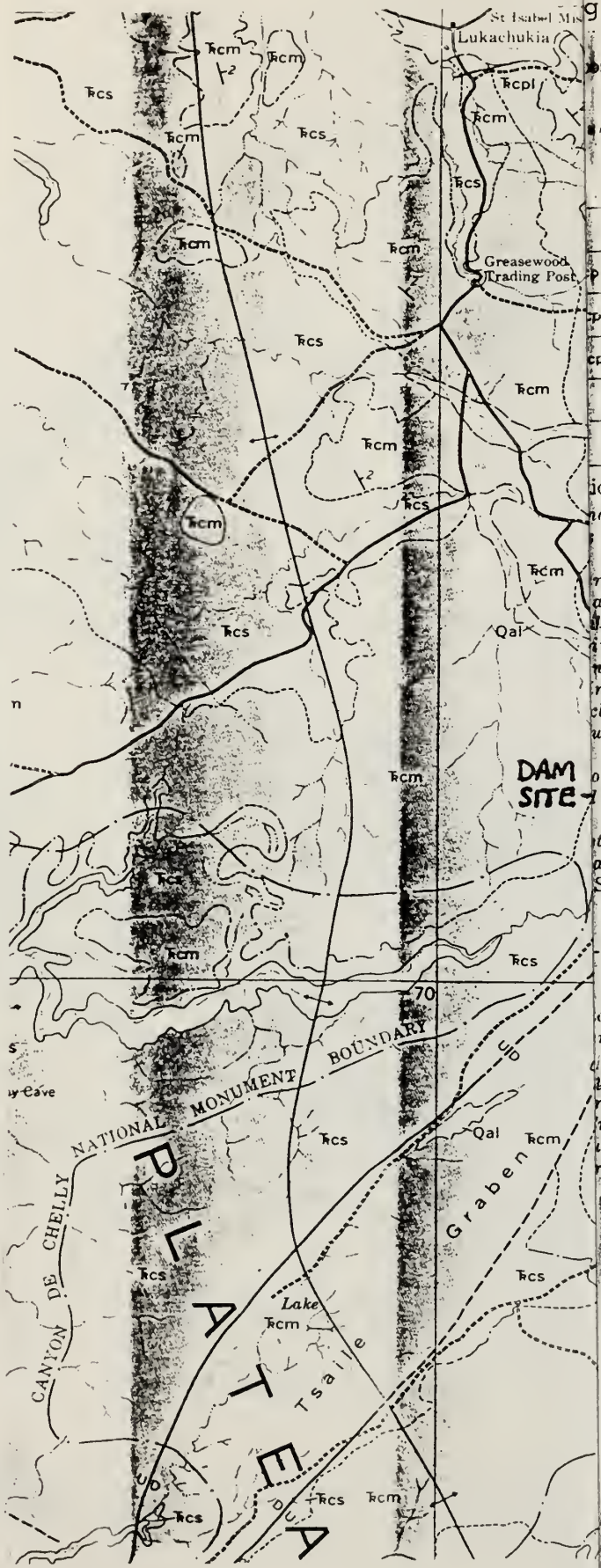
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FIGURES



gend

osits

ion

...arump Member ... undifferentiated in Mon... Includes only Owl Rock ...rvations. Church Rock ...and silty sandstone and ...lty sandstone in the Mon...valent of the Rock Point ...ne. Owl Rock Member, ...nk interbedded limestone ...cludes Hite Bed in Monu...uan River. Hite Bed is a

...or Butte Members undif... 22 in eastern Monument

...tone, siltstone, and minor ...ance Plateau, upper and ...Sandstone Bed, recognized

...gray sandstone and con-

...one, sandstone, and lime... part of Petrified Forest

...y to yellowish-gray sand... Butte Member between ...reek, Mesa Redondo Mem..., and sandstone and silt... area mapped with unit

Contact

Dashed where approximately located

Indefinite contact

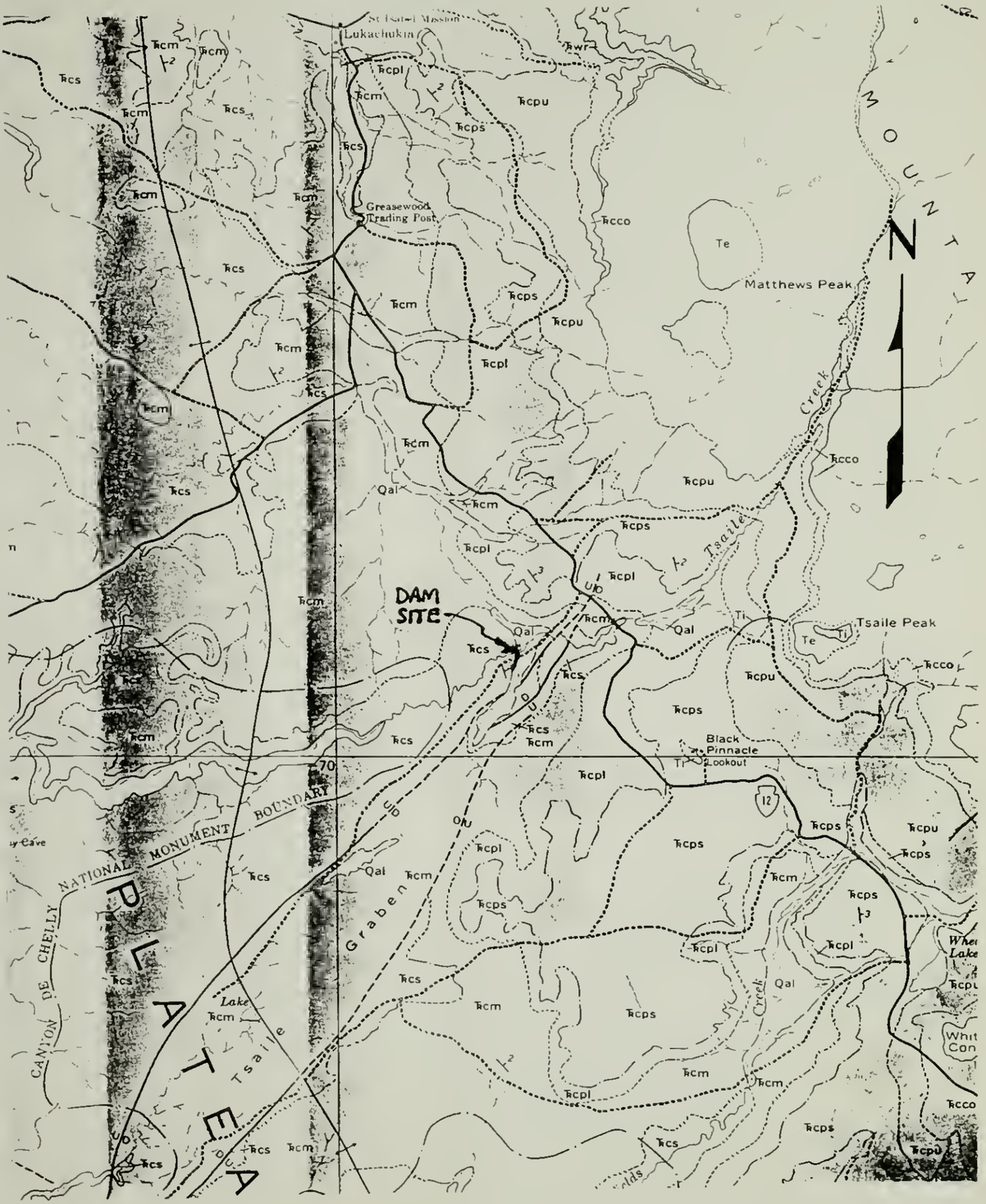
Used for showing surficial deposits where contact is generalized in order to simplify detail

Gradational contact

Used to show approximate boundaries of units having gradational contacts

...of beds

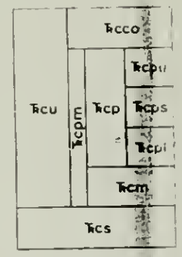
FIGURE 1 Geology Map of Area



Geologic Legend

Surficial deposits

Qal — Qal, *alluvium*



Chinle Formation

Tcu, *Chinle Formation excluding Shinarump Member*

Tcco, *Church Rock and Owl Members undifferentiated in Monument Valley-Piute Canyon area. Includes only Owl Rock Member in other parts of the reservations. Church Rock Member, reddish-brown siltstone and silty sandstone and grayish-orange-pink mudstone to silty sandstone in the Monument Valley area. Lateral equivalent of the Rock Point Member of the Wingate Sandstone. Owl Rock Member, mottled light-gray and greyish-pink cut-bedded limestone and calcareous siltstone. Also includes Hite Bed in Monument Valley area and along San Juan River. Hite Bed is a pale-reddish to purple sandstone*

Tcpm, *Petrified Forest and Monitor Butte Members undifferentiated; quadrangles 9, 10, and 15 in eastern Monument Valley*

Tcp, *Petrified Forest Member, claystone, siltstone, and minor amounts of sandstone. On Defiance Plateau, upper and lower parts, separated by Sonsela Sandstone Bed, recognized but not differentiated*

Tcpu, *upper part*

Tcps, *Sonsela Sandstone Bed, light-gray sandstone and conglomerate*

Tcpl, *lower part*

Tcm, *Monitor Butte Member, siltstone, sandstone, and lime-pellet conglomerate; includes lower part of Petrified Forest Member in Monument Valley area*

Tcs, *Shinarump Member, light-gray to yellowish-gray sandstone and conglomerate; Monitor Butte Member between Lupton and the canyon of Black Creek, Mesa Redondo Member in southern Defiance Plateau, and sandstone and siltstone member in Cameron-Lees Ferry area mapped with unit*

U / D
Fault
Dashed where approximately located. U, upthrown side; D, downthrown side

Anticline
Showing trace of axial plane and direction of plunge. Dashed where approximately located

Contact
Dashed where approximately located

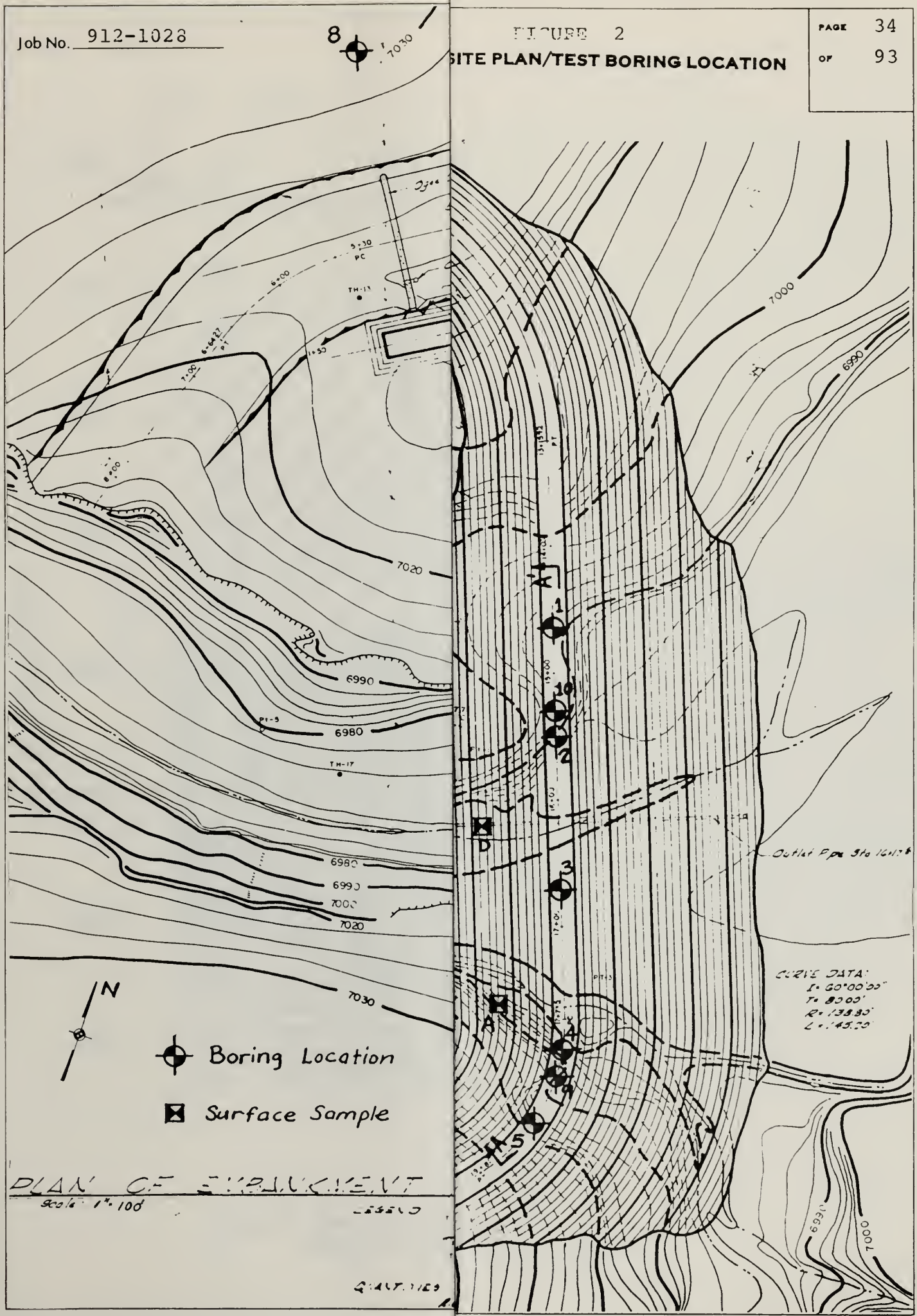
Indefinite contact
Used for showing surficial deposits where contact is generalized in order to simplify detail

Gradational contact
Used to show approximate boundaries of units having gradational contacts

50
Strike and dip of beds

E

FIGURE 2
SITE PLAN/TEST BORING LOCATION

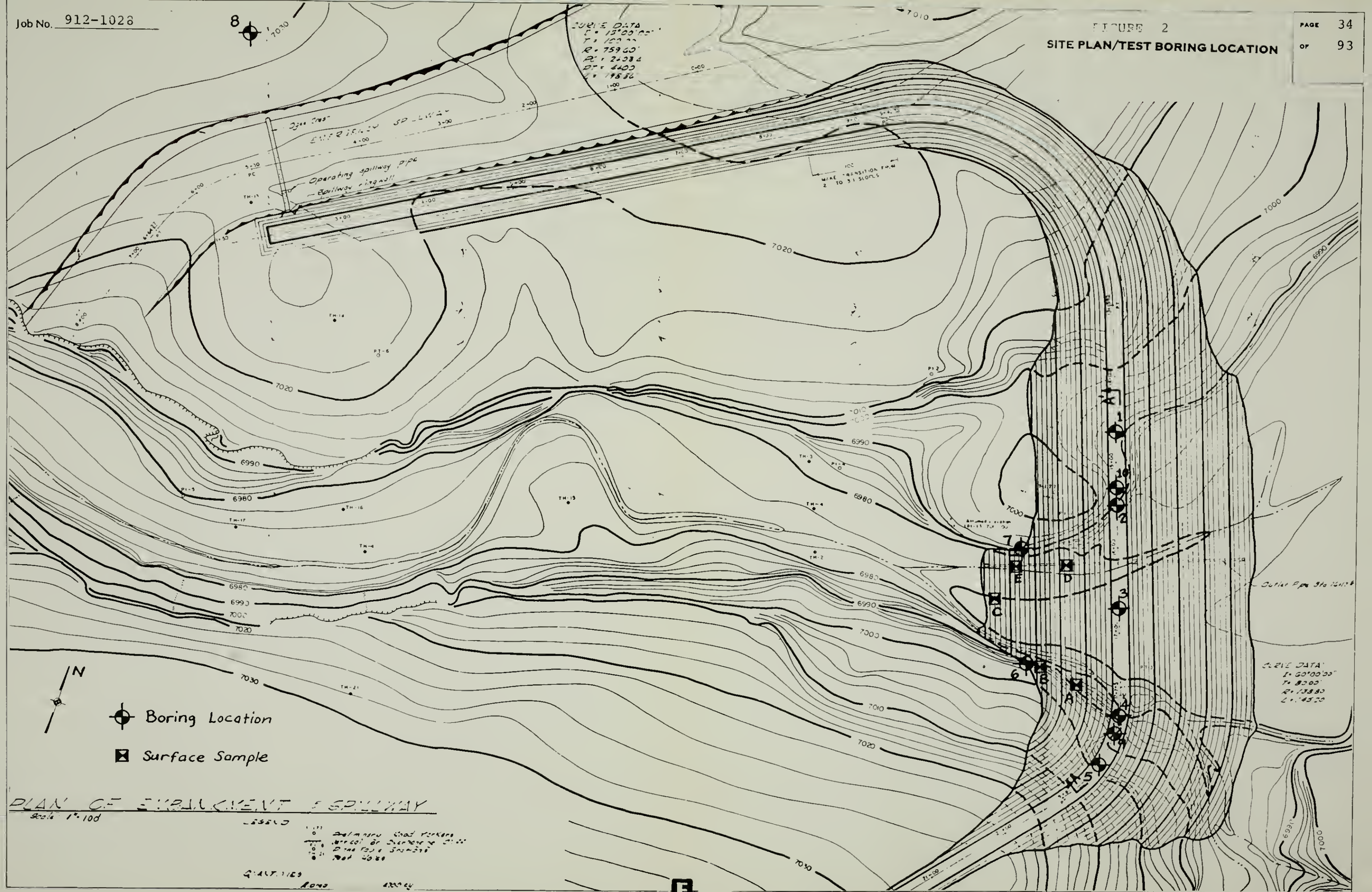


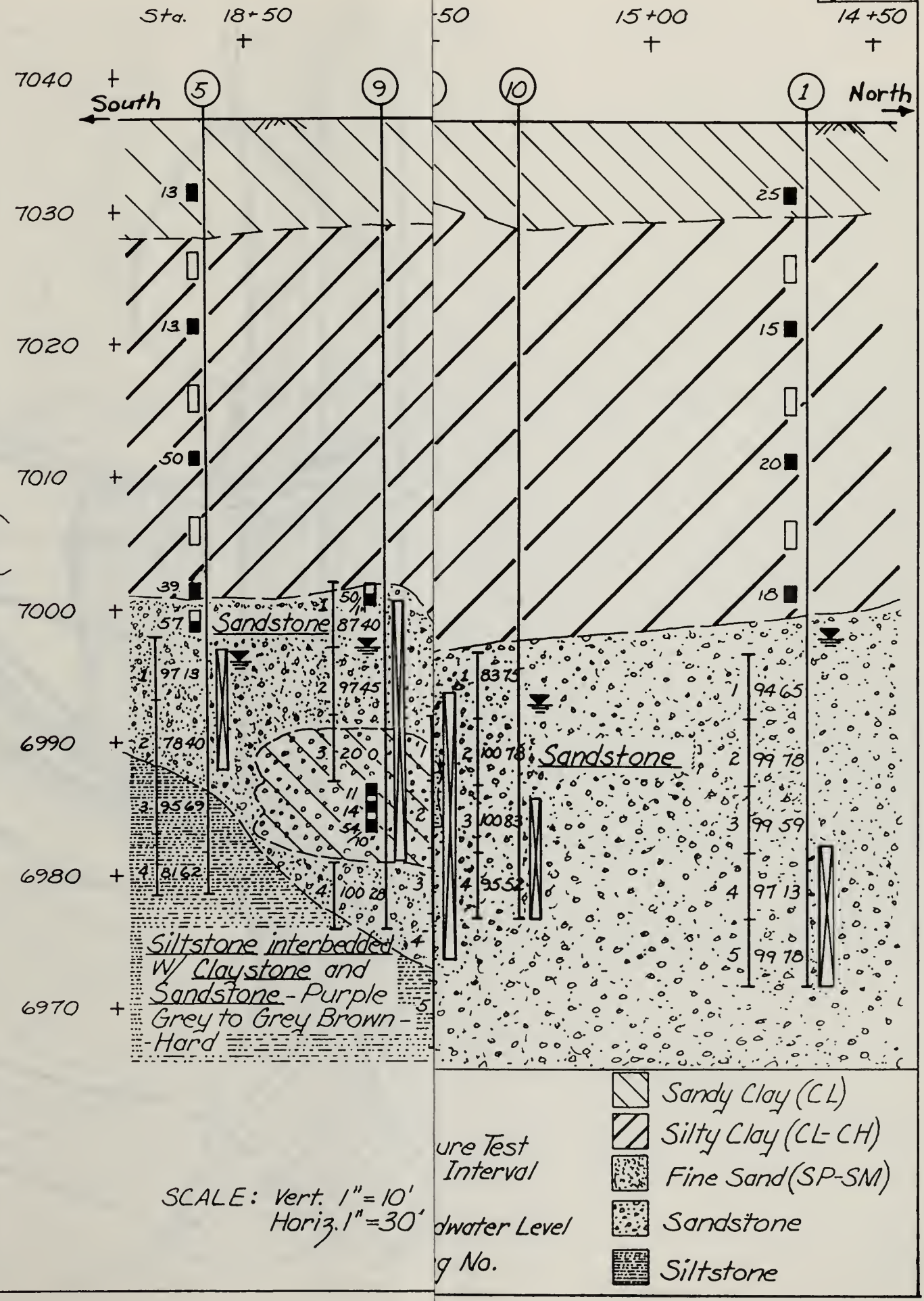
PLAN OF EMBANKMENT
Scale 1" = 100'

Job No. 912-1028

FIGURE 2

SITE PLAN/TEST BORING LOCATION




Sta. 18+50
15+00
14+50
7040
7030
7020
7010
7000
6990
6980
6970
ELEVATION (FT.)
South
North
5
9
10
1
Sandstone
Sandstone
Siltstone interbedded W/ Claystone and Sandstone - Purple Grey to Grey Brown - Hard
Sandy Clay (CL)
Silty Clay (CL-CH)
Fine Sand (SP-SM)
Sandstone
Siltstone
SCALE: Vert. 1"=10'
Horiz. 1"=30'
ure Test
Interval
dwater Level
g No.

Job No. 912-1028

GEOLOGICAL PROFILE A-A'

FIGURE 3

Sta. 18+50 | 18+00 | 17+50 | 17+00 | 16+50 | 16+00 | 15+50 | 15+00 | 14+50

South ← (5) (9) (4) (3) (2) (10) (1) → North

Existing Grade (Top of Dam)

Sandy Clay - Reddish Brown - Low Plasticity - Stiff - (CL- Fill)

Silty Clay - Reddish Brown - Med. to High Plasticity - Stiff - (CL-CH Fill)

Sandstone

Sandy Clay/Clayey Sand w/Sandstone Fragments and Gravels - Reddish Brown

Fine Sand - tr. to so. Silt and Gravel - Grey Brown - Med. Dense - (SP-SM. Alluvium)

Sandstone - Fine Grained - Grey and - Moderately Fractured to - Hard

Slightly Brown - Thinly Bedded (horiz.) Very Fractured - Slightly Weathered

Siltstone interbedded w/ Claystone and Sandstone - Purple Grey to Grey Brown - Hard

ELEVATION (FT.)

7040 + 7030 + 7020 + 7010 + 7000 + 6990 + 6980 + 6970 +

SCALE: Vert. 1" = 10'
Horiz. 1" = 30'

LEGEND

- ■ - Ring Sample (Blows/ft.)
- ■ - Standard Penetration Test (Blows/ft.)
- ▯ - 3" Shelby Tube
- A | B C - A = Run No., B = Recovery (%), C = RQD. (%)
- ▯ - Pressure Test Depth Interval
- ▽ - Groundwater Level
- (3) - Boring No.

- Sandy Clay (CL)
- Silty Clay (CL-CH)
- Fine Sand (SP-SM)
- Sandstone
- Siltstone

FIGURE 4

Plan for Proposed Grouting Program

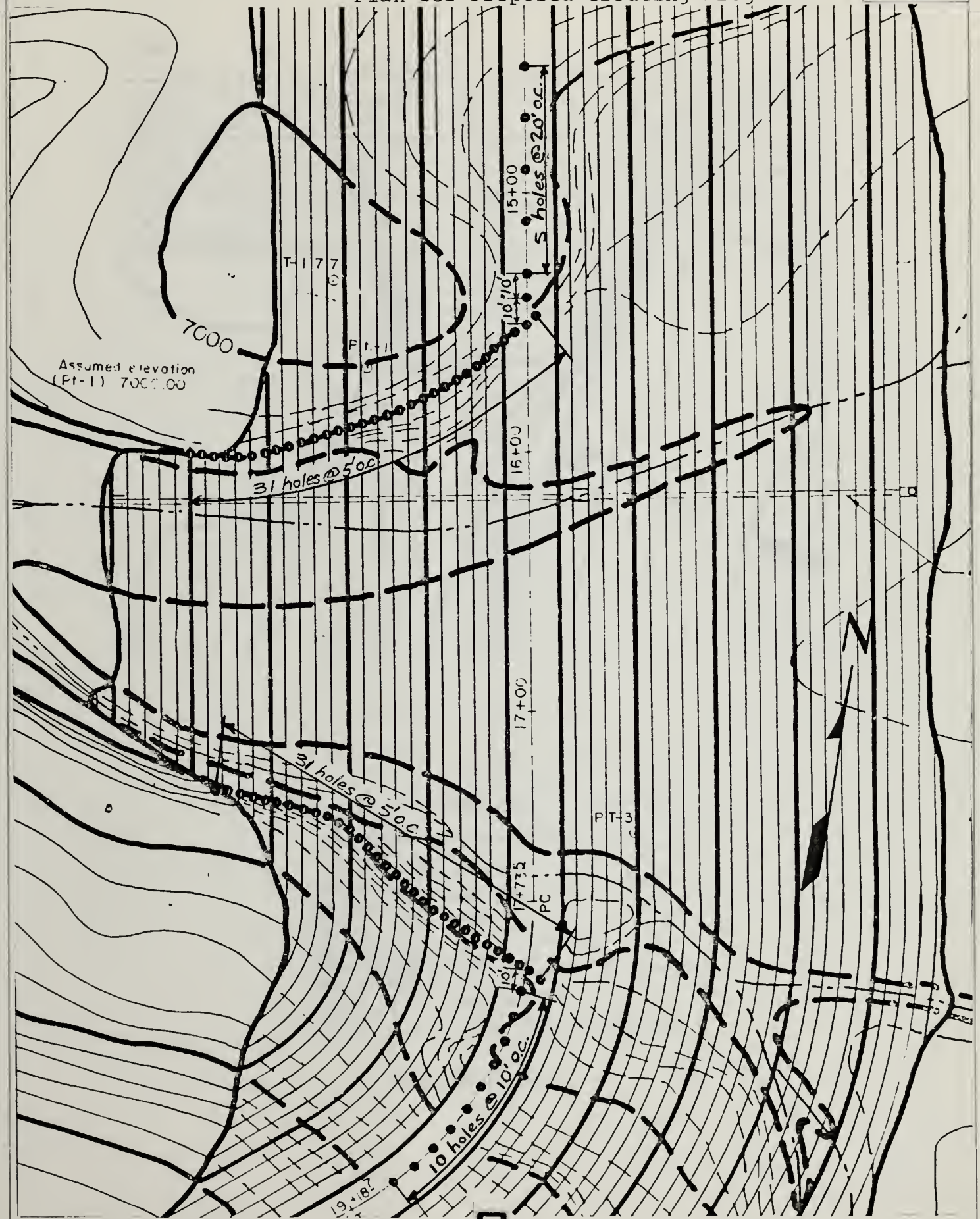
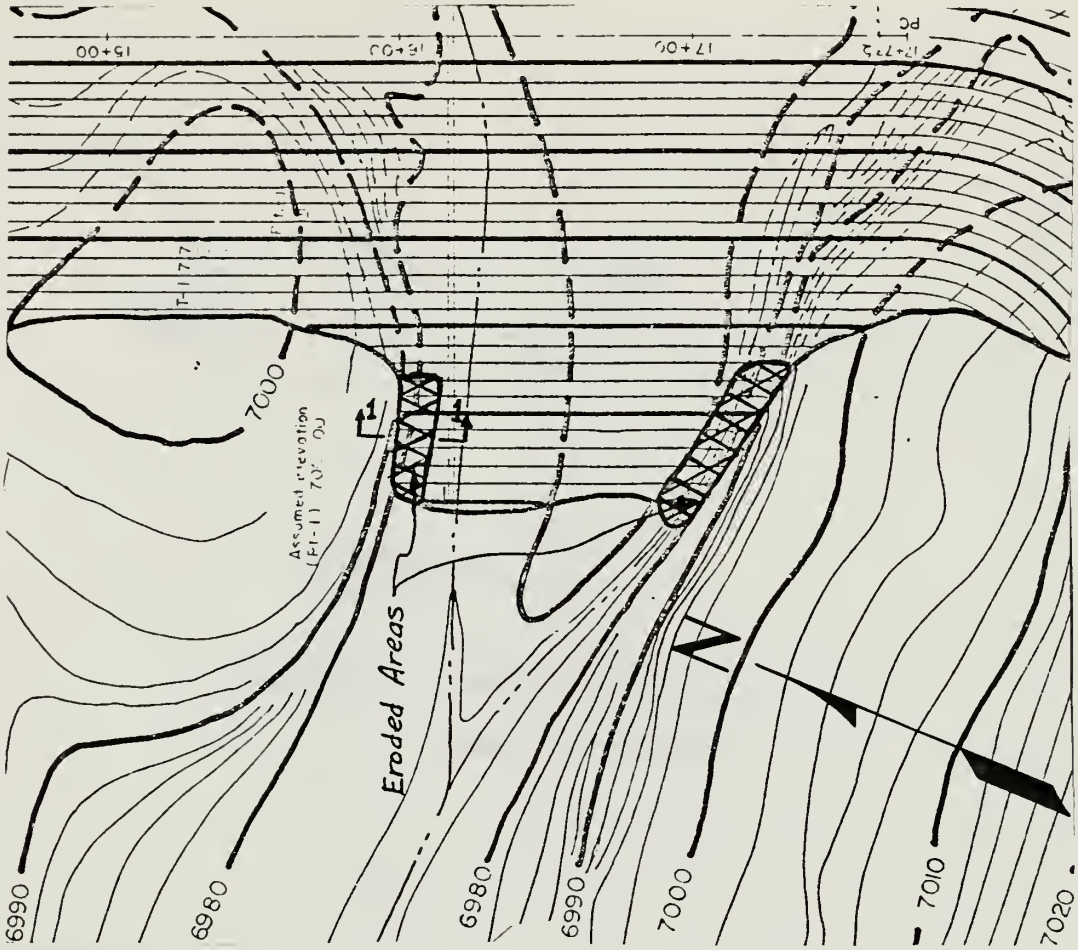
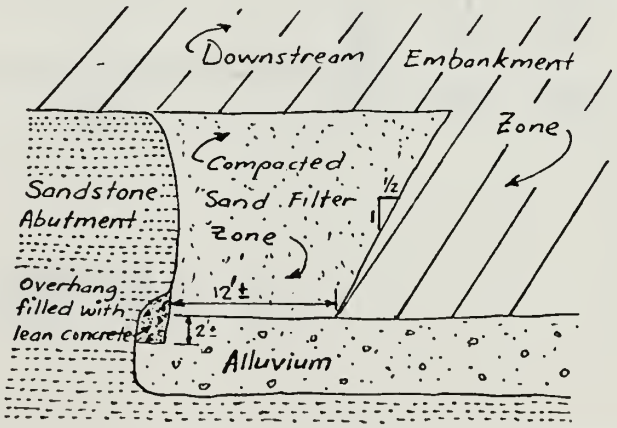


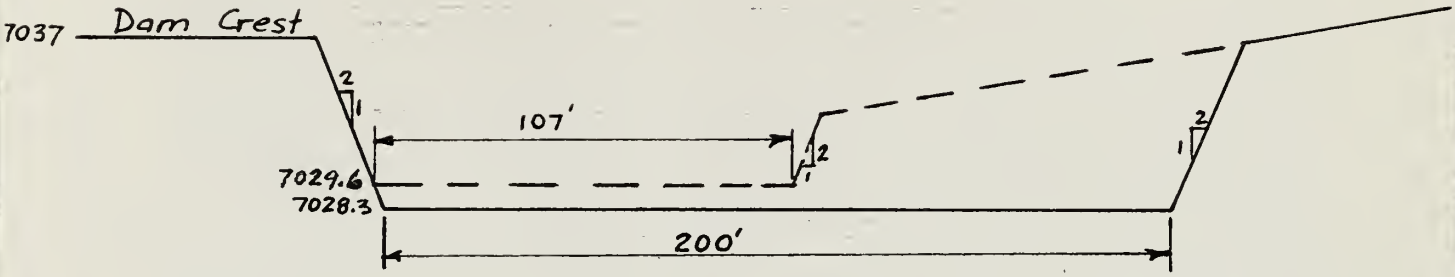
FIGURE 5
PLAN AND SECTION SHOWING
ERODED AREA AT DOWNSTREAM
TOE





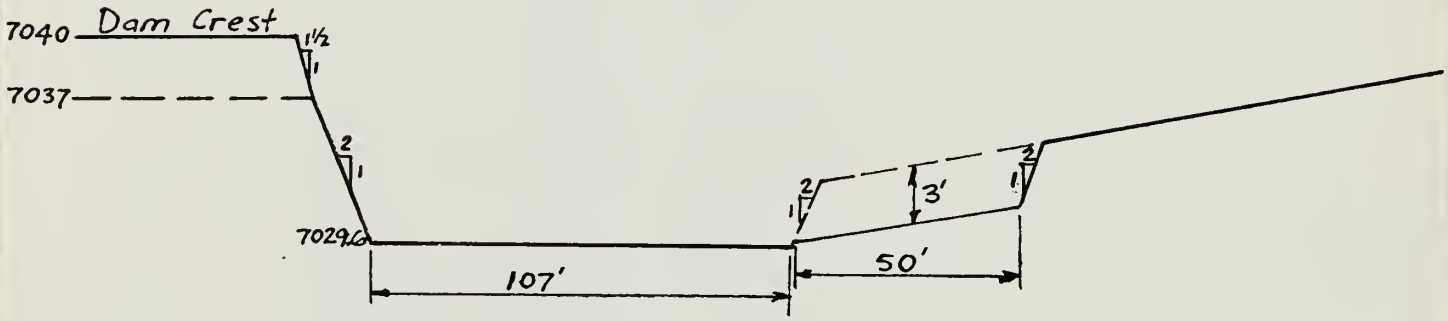
SECTION 1-1

FIGURE 6
Proposed Spillway Modifications



OPTION 1

Scales: Horiz. 1" = 50'
Vert. 1" = 10'



OPTION 2

Legend

——— Proposed Grade

– – – Existing Grade

APPENDIX A

Boring Logs
Pressure Test Results
Summary of Pressure Test Results

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 1 | Job No. 912-1028

Elev. Top of Hole: 7037 | Datum: MSL | Prepared By: J. Duffield | Date: 11/18/79

Type/Size of Boring: 7" Hollow Stem | Date: 11/18/79 | Driller: T. Kulik | Reviewed By: TCA | Date: 1/16/80

Depth Ft	Penetration Resistance Blows/Ft C	Penetration Resistance Blows/Ft N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max. Size In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med. Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
1					-PL		SANDY CLAY, SOME SILT, TRACE GRAVEL;	CL	1"			Tr	20	60	x	x x		x	x	x	x
2					+PL		Reddish Brown, low plasticity						40	80							
3							(embankment fill)														
4																					
5																					
6		25	R	No Recovery																	
7																					
8					+PL		SILTY CLAY, TR. TO SOME SAND, TR.	CL-CH	½"			Tr	10	80	x	x x		x	xx	x	x
9							GRAVEL; Reddish Brown, medium to						20	90							
10							high plasticity (embankment fill)														
1		9"Rec.	T	115.5	13.9																
2																					
3																					
4																					
5																					
6		15	R	104.3	18.7																
7																					
8																					
9																					
20																					
1		20"Rec.	T	107.7	21.7																
2																					
3																					
4																					
5																					
6		20	R	106.6	21.3																
7																					
8																					
9																					
30																					

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 1 (Continued) | Job No. 912-1028

Elev. Top of Hole | Datum | Prepared By: J. Duffield | Date: 11/18/79

Type/Size of Boring: 7" Hollow Stem & NX Core | Date: 11/18/79 | Driller: T. Kulik | Reviewed By | Date

Depth Ft	Penetration Resistance Blows/Ft. C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max. Size in.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med. Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
31		22"Rec.	T	114.0	17.0 +PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH	½"			Tr	10	80	X	X X		X	XX	X	X
32													20	90							
33																					
34																					
35																					
36		18	R	105.7	20.1																
37																					
38							SANDSTONE; Light Grey to slightly Brown, predominately fine grained and well sorted, non-calcareous, slightly weathered. Moderately fractured with horizontal fractures along cross-stratification layers. Occasional thin vertical cracks. Thin seams (1/32" to 1/4") of micaceous clay present @ 46.3', 48.4', 48.9', and 51.0'.	Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %									
39									3/4												
40									1 1/2												
41								1	1 1/2	Yes	94	65									
42									1 1/2												
43									1 1/2												
44									1 1/2												
45									1 1/2												
46									1 1/4												
47								2	1	Yes	99	78									
48									1												
49									1												
50									1												
51									1 1/4												
52									1 1/4												
53								3	1	Yes	99	59									
54									1												
55							Grain size increasing slightly and traces and stringers of coal below 55'; very fractured from 55'-59'.		1												
56									1												
57									3/4												
58								4	3/4	Yes	97	13									
59									3/4												
60									3/4												

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E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 1 (Continued) Job No. 912-1028

Elev. Top of Hole Datum Prepared By J. Duffield Date 11/18/79

Type/Size of Boring NX Core Date 11/18/79 Driller T. Kulik Reviewed By Date

Depth Ft	Penetration Resistance Blows/Ft. C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %
61							SANDSTONE; Light Grey to slightly		1			
2							Brown, predominately fine grained		3/4			
3							and well sorted, non-calcareous,	5	3/4	Yes	99	78
4							slightly weathered. Moderately		3/4			
5							fractured with horizontal fractures		3/4			
6							along cross-stratification layers.					
7							Occasional thin vertical cracks.					
8												
9												
70												
1												
2												
3												
4							Stopped at 65'					
5							Hole damp at 39' on 11/19/79					
6							Pressure tests performed between depths of 54.3' and 65.0'.					
7												
8												
9												
80												
1												
2												
3												
4												
5												
6												
7												
8												
9												
90												

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

WATER PRESSURE TESTING IN CORE DRILL HOLES

PROJECT Tsaile Dam Evaluation

HOLE NO. #1 DATE 11/19/79

Test No. 1
Test Pressure 10 PSI
Test Depth From 54.3' To 65.0'

TIME MIN.	METER READING	WATER GAL.
0	6215.3	--
1	6217.4	2.10
2	6217.8	0.4
3	6217.9	0.1
4	6217.9	0
5	6217.9	0
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = 2.6
AVG. TAKE = 0.1 GPM

Test No. 2
Test Pressure 30 PSI
Test Depth From 54.3' To 65.0'

TIME MIN.	METER READING	WATER GAL.
0	6217.9	--
1	6218.5	0.6
2	6218.6	0.1
3	6218.7	0.1
4	6218.7	0
5	6218.7	0
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = 0.8
AVG. TAKE = 0.1 GPM

Test No. _____
Test Pressure _____ PSI
Test Depth From _____ To _____

TIME MIN.	METER READING	WATER GAL.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = _____
AVG. TAKE = _____ GPM

REMARKS Height of water swivel above ground surface is 14.5', while the pressure gauge was 5.3' above the ground level.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 2 Job No. 912-1028

Elev. Top of Hole: 7037 Datum: MSL Prepared By: J. Duffield Date: 11/4/79

Type/Size of Boring: 7" Hollow Stem Date: 11/4/79 Driller: T. Kulik Reviewed By: TCA Date: 1/16/80

Depth Ft	Penetration Resistance Blows/Ft C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max. Size. In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
1					-PL		SANDY CLAY, SOME SILT, TRACE GRAVEL;	CL	1"			Tr	20	60	x	x x		x	x	x	x
2							Reddish Brown, low plasticity						40	80							
3							(embankment fill)														
4					+PL																
5																					
6																					
7					+PL		SILTY CLAY, TR. TO SOME SAND, TR.	CL-CH	½"			Tr	10	80	x	x x		x	xx	x	x
8							GRAVEL; Reddish Brown, medium to						20	90							
9							high plasticity (embankment fill)														
10																					
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
20																					
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
30																					

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 2 (Continued) | Job No. 912-1028

Elev. Top of Hole | Datum | Prepared By: J. Duffield | Date: 11/4/79

Type/Size of Boring: 7" auger NX Core | Date: 11/4/79 | Driller: T. Kulik | Reviewed By | Date

Depth Ft	Penetration Resistance Blows/Ft C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max. Size, in.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
31					+PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH	½"			Tr	10	80	x	x x		x	xx	x	x
2													20	90							
3					+PL																
4																					
5																					
6																					
7																					
8																					
9																					
40																					
								Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %									
1		50/3"	S	No Rec.			SANDSTONE; Light Grey, fine grained non-calcareous, slightly weathered. Moderately fractured with horizontal fractures containing brown clayey material @ 40.5', 41.3', 42.3', 42.7', 43.4', 44.4'. Some vertical cracks present.		1												
2									1												
3								1	1	None	95	57									
4									1												
5									1												
6									3/4												
7									3/4												
8								2	3/4	None	56	38									
9							GRAVELS; Grey, well sorted, medium to coarse grained, rounded. (Probable Alluvium - caves badly)		3/4												
50									1/2												
1									1/2												
2									1/2												
3								3	3/4	None	47	13									
4							SANDSTONE; Light Grey, fine grained, non-calcerous, weathered and somewhat friable. Moderately fractured with horizontal fractures often filled with thin gray clay seams.		1												
5									1												
6									3/4												
7									3/4												
8								4	1/2	None	93	53									
9									1/2												
60									3/4												

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 2 (Continued) Job No. 912-1028

Elev. Top of Hole Datum Prepared By J. Duffield Date 11/4/79

Type/Size of Boring NX Core Date 11/4/79 Driller T. Kulik Reviewed By Date

Depth Ft	Penetration Resistance Blows/Ft. C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %
61							SANDSTONE; Light Grey, fine to		1/2			
2							medium grained non-calcareous.	5	3/4	None	98	92
3							Moderately fractured.		1			
4												
5												
6							Stopped at 63'					
7							Groundwater level measured at 45' on					
8							11/6/79 and 11/7/79					
9												
70							Pressure tests performed between					
1							the depths of 43' and 63'.					
2												
3												
4												
5												
6												
7												
8												
9												
80												
1												
2												
3												
4												
5												
6												
7												
8												
9												
90												

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

WATER PRESSURE TESTING IN CORE DRILL HOLES

PROJECT Tsaile Dam Evaluation

HOLE NO. #2 DATE 11/7/79

Test No. 1
Test Pressure 5 PSI
Test Depth From 43' To 63'

TIME MIN.	METER READING	WATER GAL.
0	2899.8	--
1	2909.5	9.7
2	2910.8	1.3
3	2921.4	10.6
4	2932.3	10.9
5	2942.5	10.2
6	2953.0	10.5
7	2963.4	10.4
8	2973.5	10.1
9	2983.3	9.8
10		
11		
12		
13		
14		
15		

TOTAL = 83.5
AVG. TAKE = 9.3 GPM

Test No. 2
Test Pressure 10 PSI
Test Depth From 43' To 63'

TIME MIN.	METER READING	WATER GAL.
0	3000.1	--
1	3029.3	29.2
2	3035.6	6.3
3	3051.2	15.6
4	3072.5	21.3
5	3083.6	11.1
6	3109.9	26.3
7	3116.9	7.0
8	3131.7	14.8
9	3147.6	15.9
10	3163.1	15.5
11	3178.2	15.1
12	3194.9	16.7
13	3207.7	12.8
14	3218.4	10.7
15		

TOTAL = 218.3
AVG. TAKE = 15.6 GPM

Test No. 3
Test Pressure 15 PSI
Test Depth From 43' To 63'

TIME MIN.	METER READING	WATER GAL.
0	3247.6	--
1	3266.3	18.7
2	3294.6	28.3
3	3324.9	30.3
4	3354.3	29.4
5	3383.4	29.1
6	3411.8	28.4
7	3440.2	28.4
8	3469.5	29.3
9	3498.8	29.3
10	3527.9	29.1
11	3554.3	26.4
12	3582.6	28.3
13	3610.5	27.9
14	3637.4	26.9
15	3664.8	27.4

TOTAL = 417.2
AVG. TAKE = 27.8 GPM

REMARKS Hole caved to 52' below ground level. Height of water swivel at 13.8' above ground level, while pressure gauge at 5.0' above ground surface.

WATER PRESSURE TESTING IN CORE DRILL HOLES

PROJECT Tsaile Dam Evaluation

HOLE NO. #2 DATE 11/7/79

Test No. 4
Test Pressure 10 PSI
Test Depth From 43' To 63'

TIME MIN.	METER READING	WATER GAL.
0	3686.9	--
1	3698.5	11.60
2	3734.3	35.80
3	3760.1	25.80
4	3790.0	29.90
5	3817.6	27.60
6	3844.8	27.20
7	3869.6	24.80
8	3895.9	26.3
9	3920.0	24.1
10	3945.6	25.6
11	3971.1	25.5
12	3995.9	24.8
13		
14		
15		

TOTAL = 309.0
AVG. TAKE = 25.75 GPM

Test No. 5
Test Pressure 5 PSI
Test Depth From 43' To 63'

TIME MIN.	METER READING	WATER GAL.
0	4007.2	--
1	4007.8	0.6
2	4007.3	0
3	4006.9	0
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = 0.6
AVG. TAKE = 0.2 GPM

Test No.
Test Pressure PSI
Test Depth From To

TIME MIN.	METER READING	WATER GAL.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL =
AVG. TAKE = GPM

REMARKS See sheet 1 of 2

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 3 Job No. 912-1028

Elev. Top of Hole: 7037 Datum: MSL Prepared By: J. Duffield Date: 11/20/79

Type/Size of Boring: 7" Hollow Stem Date: 11/20/79 Driller: T. Kulik Reviewed By: TCA Date: 1/17/80

Depth Ft	Penetration Resistance Blows/Ft C	Penetration Resistance Blows/Ft N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max Size. In	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
1					+PL		SANDY CLAY, SOME SILT, TRACE GRAVEL; Reddish Brown, low plasticity (embankment fill)	CL	1"			Tr	20	60	x	x x		x	x	x	x
2													40	80							
3																					
4																					
5																					
6		1'8" Rec.	T	103.2	22.7																
7																					
8																					
9					+PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH	½"			Tr	10	80	x	x x		x	xx	x	x
10													20	90							
1		12	R	96.8	23.9																
2																					
3																					
4																					
5																					
6		13"Rec.	T	109.6	20.5																
7																					
8																					
9																					
20																					
1		22	R		25.2																
2																					
3																					
4																					
5																					
6		17"Rec.	T	121.4	12.7																
7																					
8																					
9																					
30																					

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E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 3 (Continued) | Job No. 912-1028

Elev. Top of Hole | Datum | Prepared By: J. Duffield | Date: 11/20/79

Type/Size of Boring: 7" Hollow Stem & NX Core | Date: 11/20/79 | Driller: T. Kulik | Reviewed By | Date

Depth Ft	Penetration Resistance Blows/Ft C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max Size In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well / Med. / Poor	Grain Shape Angular / Subangular / Rounded / Subrounded	Relative Density Low / Med / High	Dry Strength None / Very Low / Low / Medium / High / Very High	Plasticity None / Low / Medium / High	Consistency Soft / Firm / Stiff / Very Stiff / Hard	Cementation None / Light / Moderate / Heavy
31		42	R	108.3	12.0 +PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH	½"			Tr	10 20	80 90	x	x x			x	xx	x	x
40		50/10"	R	112.3	14.2																
1		20	R		16.6																
5		46	S																		
50		12"Rec.	T	114.0	18.4		FINE SAND, TRACE SILT AND ROUNDED GRAVELS; Grey Brown, predominantly fine to very fine sand. (Alluvium)	SP				Tr	90 95	Tr	x	x	x	x	x			x
6		50/5"	R				SANDSTONE; Grey, fine grained, non-calcareous, traces of coal.														
60																					

Run No. 1 | Coring Time mins/ft 1 1/4 | Drill Water Return | Recovery % | RQD %

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 3 (Continued) Job No. 912-1028

Elev. Top of Hole Datum Prepared By J. Duffield Date 11/20/79

Type/Size of Boring NX Core Date 11/20/79 Driller T. Kulik Reviewed By Date

Depth Ft	Penetration Resistance Blows/Ft C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %
61							SANDSTONE; Grey, fine grained, non-calcareous. Moderately fractured with very thin micaceous clay seams in horizontal fractures @ 60.8' and 62.9'.	1	2	None	98	78
2									3/4			
3									3/4			
4									1			
5												
6												
7												
8							Stopped at 64'					
9							Groundwater level at 49'					
70												
1												
2												
3												
4												
5												
6												
7												
8												
9												
80												
1												
2												
3												
4												
5												
6												
7												
8												
9												
90												

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 4 Job No. 912-1028

Elev. Top of Hole: 7037+ Datum: Prepared By: J. Duffield Date: 11/8/79

Type/Size of Boring: 7" Hollow Stem Date: 11/8/79 Driller: T. Kulik Reviewed By: TCA Date: 1/17/80

Depth Ft	Penetration Resistance Blows/Ft. C	Penetration Resistance Blows/Ft. N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max. Size In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
1					+PL		SANDY CLAY, SOME SILT, TRACE GRAVEL; Reddish Brown, low plasticity (embankment fill)	CL	1"			Tr	20	60	x	x x		x	x	x	x
2													40	80							
3																					
4																					
5																					
6																					
7																					
8																					
9					+PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH	½"			Tr	10	80	x	x x		x	xx	x	x
10													20	90							
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
20																					
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
30																					

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 4 (Continued) | Job No. 912-1028

Elev. Top of Hole | Datum | Prepared By J. Duffield | Date 11/8/79

Type/Size of Boring 7" Hollow Stem & NX Core | Date 11/8/79 | Driller T. Kulik | Reviewed By | Date

Depth Ft	Penetration Resistance Blows/Ft C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max. Size In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well / Med / Poor	Grain Shape Angular / Subangular / Rounded / Subrounded	Relative Density Low / Med / High	Strength None / Very Low / Low / Medium / High / Very High	Density None / Low / Medium / High	Consistency Soft / Firm / Stiff / Very Stiff / Hard	Cementation None / Slight / Moderate / Heavy
31					+PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH	½"			Tr	10 20	80 90	x	x x		x	xx	x	x
40		23	R	106.9	21.2																
		30	R	106.9	19.5																
		21	S																		
		22	S																		
50							SANDSTONE; Grey, fine grained, non-calcareous, slightly weathered. Very fractured with horizontal fractures filled with Reddish Brown clay from 45'-50'.	1	3/4 1 2 1 1/4 1 1/2	Yes	30	7									
							From 50'-55', only recovery was a few clay lumps and a couple of rounded gravels.	2	1 1/2 1/2 1/2 1/2 1/2	Yes	3	0									
60							No recovery from 55'-56.8'. Sandstone very fractured from 57'-60', with vertical fracture at 58'-59'.	3	1 1/2 3/4 1 1/4 3 1/4	Yes	65	37									

Run No. | Coring Time mins/ft | Drill Water Return | Recovery % | RQD %

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E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 4 (Continued) Job No. 912-1028

Elev. Top of Hole Datum Prepared By J. Duffield Date 11/8/79

Type/Size of Boring NX Core Date 11/8/79 Driller T. Kulik Reviewed By Date

Depth Ft	Penetration Resistance Blows/Ft C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %
61							SANDSTONE; Grey, fine grained predominately, non-calcareous, slightly weathered. Medium to coarse grained from 60'-61.5', and coal present from 60'-63.5' and very fractured and friable from 65.5' to 66.5'.		1 1/4			
2									1 1/2			
3								4	3/4	Yes	95	73
4									1			
5									1 1/4			
6									1/2			
7									3 1/2			
8							SILTSTONE; Grey-Brown, interbedded with very fine sandstone, non-calcareous, very hard. Fracture at 67.8'.	5	5	Yes	83	47
9									4			
70									3			
1												
2												
3												
4												
5							Stopped at 70'					
6							Groundwater level at 43' on 11/15					
7							and 11/16/79					
8												
9							Pressure tests performed between					
80							49' and 58.5'.					
1												
2												
3												
4												
5												
6												
7												
8												
9												
90												

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

WATER PRESSURE TESTING IN CORE DRILL HOLES

PROJECT Tsaile Dam Evaluation

HOLE NO. #4 DATE 11/15/79

Test No. 1
Test Pressure 15 PSI
Test Depth From 49' To 58.5'

TIME MIN.	METER READING	WATER GAL.
0	4064.7	
1	4076.7	12.0
2	4080.6	3.9
3	4080.7	0.1
4	4080.7	0
5	4080.7	0
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = 16
AVG. TAKE = 3.2 GPM

Test No. _____
Test Pressure _____ PSI
Test Depth From _____ To _____

TIME MIN.	METER READING	WATER GAL.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = _____
AVG. TAKE = _____ GPM

Test No. _____
Test Pressure _____ PSI
Test Depth From _____ To _____

TIME MIN.	METER READING	WATER GAL.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = _____
AVG. TAKE = _____ GPM

REMARKS Height of water swivel above ground surface was 12.5', while pressure gauge was 5.3' above ground level.

NOTE: Other pressure tests were tried within this depth range, but were unsuccessful due to leakage caused by inability to get upper packer to seat properly.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 5 | Job No. 912-1028

Elev. Top of Hole: 7037 | Datum: MSL | Prepared By: J. Duffield | Date: 11/30/79

Type/Size of Boring: 7" Hollow Stem | Date: 11/30/79 | Driller: T. Kulik | Reviewed By: TCA | Date: 1/17/80

Depth Ft	Penetration Resistance Blows/Ft C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max Size In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med. Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
1					-PL		SANDY CLAY, SOME SILT, TRACE GRAVEL; Reddish Brown, low plasticity (embankment fill)	CL	1"			Tr	20	60	x	x x		x	x	x	x
2													40	80							
3																					
4																					
5					+PL																
6		13	R	106.0	20.0																
7																					
8																					
9																					
10					+PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH	½"			Tr	10	80	x	x x		x	xx	x	x
1		1'9" Rec.	T	101.0	24.9								20	90							
2																					
3																					
4																					
5																					
6		13	R	104.7	20.9																
7																					
8																					
9																					
20																					
1		8"Rec.	T	105.5	23.7																
2																					
3																					
4																					
5																					
6		50	R	107.4	19.0																
7																					
8																					
9																					
30																					

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation — No. 5 (Continued) — Job No. 912-1028

Elev. Top of Hole — Datum — Prepared By J. Duffield — Date 11/30/79

Type/Size of Boring 7" Hollow Stem & NX Core — Date 11/30/79 — Driller T. Kulik — Reviewed By — Date 12/1/79

Depth Ft	Penetration Resistance Blows/Ft. C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max Size, In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
31		1'8" Rec.	T	109.0	19.9 +PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH	½"			Tr	10 20	80 90	x	x x		x	xx	x	x
6		39	R		12.4																
7							SANDSTONE; Grey, fine grained, non-calcareous, very weathered at surface to moderately weathered below 40'. Very fractured to moderately fractured. Thin clay seams (1/8" to 3/8") present from 39' to 41' and 43.3'. Grain size increases from 44' to 46.5' and from 50 to 50.5'. Color changes to orange-grey below 45'. Vertical fracture between 46.5' and 47.5'. Very fractured from 49' to 50'.	Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %									
8		57	S																		
40									1												
1									3/4												
2								1	3/4	50%	97	13									
3									3/4												
4									3/4												
5									3/4												
6									1/2												
7								2	1	50%	78	40									
8									3/4												
9									3/4												
50									1												
1									3 1/2												
2							SILTSTONE AND CLAYSTONE; Purple-Grey, interbedded, non-calcareous, dense. Siltstone predominates with depth. Fractures present at 54.3' and 55.5'.	3	3	50%	95	69									
3									3 3/4												
4									2												
5									5												
6									4												
7								4	3	50%	81	62									
8									4 3/4												
9									3/4												
60							Stopped at 58.3' Groundwater level at 41' on 12/2/79														

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Pressure tests performed between 40' and 49'

WATER PRESSURE TESTING IN CORE DRILL HOLES

PROJECT Tsaile Dam Evaluation

HOLE NO. #5 DATE 12/1/79

Test No. 1
Test Pressure 10 PSI
Test Depth From 40' To 49'

TIME MIN.	METER READING	WATER GAL.
0	7109.7	--
1	7123.5	13.8
2	7135.3	11.8
3	7149.8	14.5
4	7159.2	9.4
5	7163.5	4.3
6	7166.4	2.9
7	7169.7	3.3
8	7172.8	3.1
9	7175.6	2.8
10	7178.5	2.9
11		
12		
13		
14		
15		

TOTAL = 68.8
AVG. TAKE = 6.9 GPM

Test No. 2
Test Pressure 20 PSI
Test Depth From 40' To 49'

TIME MIN.	METER READING	WATER GAL.
0	7231.9	--
1	7240.4	8.5
2	7262.6	22.2
3	7281.9	19.3
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = 50.0
AVG. TAKE = 16.7 GPM

Test No.
Test Pressure PSI
Test Depth From To

TIME MIN.	METER READING	WATER GAL.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL =
AVG. TAKE = GPM

REMARKS Height of water swivel above ground surface was 13', while pressure gauge was 4.5'.

NOTE: In test no. 2, water observed exiting top of hole, and therefore either top packer not set properly or water was leaking around packer through fractures in the rock.

E

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 6 Job No. 912-1028

Elev. Top of Hole: 7005± Datum: MSL Prepared By: J. Duffield Date: 11/29/79

Type/Size of Boring: NX Core Date: 11/29/79 Driller: T. Kulik Reviewed By: TCA Date: 1/17/80

Depth Ft	Penetration Resistance Blows/Ft. C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %
1							SANDY CLAY, SOME SILT, TRACE GRAVEL;		3			
2							Reddish Brown, low plasticity		2 3/4			
3							(embankment fill)	1	1 1/2	100%	100	48
4							SANDSTONE; Grey, fine grained, non-		1 3/4			
5							calcareous, slightly weathered.		1 3/4			
6							Moderately fractured, fractures		1 1/2			
7							along bedding planes. Thin clay		1 1/4			
8							seams (1/32" to 1/8") at 3', 3.3',	2	1	100%	100	63
9							4', 4.9', 5.3', 5.9', 7.1', 9.7',		1			
10							and from 11.3' to 13.8'.		1			
1									1 1/2			
2									3/4			
3								3	1	100%	100	67
4									1			
5									1 1/2			
6								4	3/4	100%	100	42
7									3/4			
8		1	S				SANDY CLAY, SOME SILT, TRACE GRAVEL;			None		
9							Reddish Brown, low plasticity					
20		10	S				(embankment fill)					
1		17	S				FINE SAND, TRACE SILT AND ROUNDED					
2							GRAVELS; Grey-Brown, predominantly					
3		26	S				fine to very fine sand. (Alluvium)					
4		25	S				Gravel content increasing toward					
5		72/11"	S				25'.					
6							SANDSTONE; Grey, fine grained, non-					
7							calcareous, weathered.					
8												
9							Stopped at 27'					
30							Groundwater level at 14' on 11/29/79					

Pressure tests performed between 13.5' and 27'

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

WATER PRESSURE TESTING IN CORE DRILL HOLES

PROJECT Tsaile Dam Evaluation

HOLE NO. #6 DATE 11/29/79

Test No. 1
Test Pressure 10+ PSI
Test Depth From 13.5' To 27'

TIME MIN.	METER READING	WATER GAL.
0	6960.7	--
1	6983.3	22.6
2	7004.3	21.0
3	7027.6	23.3
4	7050.7	23.1
5	7074.8	24.1
6	7099.5	24.7
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = 138.8
AVG. TAKE = 23.1 GPM

Test No. _____
Test Pressure _____ PSI
Test Depth From _____ To _____

TIME MIN.	METER READING	WATER GAL.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = _____
AVG. TAKE = _____ GPM

Test No. _____
Test Pressure _____ PSI
Test Depth From _____ To _____

TIME MIN.	METER READING	WATER GAL.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = _____
AVG. TAKE = _____ GPM

REMARKS Hole caved to depth of 22.5'. Pressure gauge was broken, so the pressure was estimated (pump running at full capacity).

Height of water swivel above ground surface was 13.5', while pressure gauge was at 5.5' above ground level.

E

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 7 | Job No. 912-1028

Elev. Top of Hole: 7006+ | Datum: MSL | Prepared By: J. Duffield | Date: 11/17/79

Type/Size of Boring: 7" Hollow Stem and NX Core | Date: 11/17/79 | Driller: T. Kulik | Reviewed By: TCA | Date: 1/17/80

Depth Ft	Penetration Resistance Blows/Ft. C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %
1					-PL		SANDY CLAY, SOME SILT, TR. GRAVEL;					
2					+PL		Reddish Brown, low plasticity (fill					
3							for drilling pad)					
4												
5							SANDSTONE; Yellow-Grey, fine grained,					
6							well sorted, non-calcareous, slightly		2			
7							weathered. Moderately fractured,		1			
8							with predominantly horizontal	1	1 1/4	Yes	98	67
9							cracks along bedding planes.		1 1/4			
10							Inclined fracture at 8.2'.		1 1/4			
1									1 3/4			
2									1 1/2			
3								2	1 1/2	Yes	98	71
4									1 1/4			
5									1			
6									1 1/4			
7								3	1 1/4	Yes	43	22
8							SOFT CLAY FILL; Reddish Brown,		3/4			
9							underlain by SILTY FINE SAND with		1/2			
20							some gravel - saturated (alluvium)		1/2			
1		3	S									
2										None		
3												
4												
5							SANDSTONE; Tan-Grey, fine grained,					
6		148/8"	S				non-calcareous, occasional thin		1			
7							stringers of coal, slightly weathered.		1 1/2			
8							Slightly coarser grained from 25'	4	1 1/4	None	98	63
9							to 26.5' and below 28'. Moderately		3			
30							fractured with horizontal fractures.		4			

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Stopped at 30'
Groundwater level at 16' on 11/18/79
Pressure tests performed 12.5' to 25'

WATER PRESSURE TESTING IN CORE DRILL HOLES

PROJECT Tsaile Dam Evaluation

HOLE NO. #7 DATE 11/17/79

Test No. 1
Test Pressure 5 PSI
Test Depth From 12.5' To 25'

TIME MIN.	METER READING	WATER GAL.
0	5562.5	--
1	5569.2	6.7
2	5580.4	11.2
3	5589.3	9.4
4	5600.2	10.4
5	5610.6	10.4
6	5620.5	9.9
7	5630.6	10.1
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = 68.1
AVG. TAKE = 9.7 GPM

Test No. 2
Test Pressure 10 PSI
Test Depth From 12.5' To 25'

TIME MIN.	METER READING	WATER GAL.
0	5630.6	--
1	5649.5	18.9
2	5670.5	21.0
3	5690.5	20.0
4	5711.5	21.0
5	5732.3	20.8
6	5753.8	21.5
7	5774.1	20.3
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = 143.5
AVG. TAKE = 20.5 GPM

Test No. 3
Test Pressure 12 (max. pressure obtainable) PSI
Test Depth From 12.5' To 25'

TIME MIN.	METER READING	WATER GAL.
0	5774.1	--
1	5804.9	30.8
2	5832.0	27.1
3	5860.2	28.2
4	5889.8	29.6
5	5916.9	27.1
6	5943.6	26.7
7	5971.8	28.2
8	6000.7	28.9
9	6028.1	27.4
10		
11		
12		
13		
14		
15		

TOTAL = 254
AVG. TAKE = 28.2 GPM

REMARKS Hole caved to 23.5'.

Height of water swivel above ground surface was 14.5', while pressure gauge was 5.3' above ground level.

Water observed to be exiting from rock at toe of dam during packer test.

E

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 8 Job No. 912-1028

Elev. Top of Hole: 7037± Datum: MSL Prepared By: J. Duffield Date: 12/3/79

Type/Size of Boring: 7" Hollow Stem, then rock bit Date: 12/3/79 Driller: T. Kulik Reviewed By: TCA Date: 1/17/80

Depth Ft	Penetration Resistance Blows/Ft. C	Penetration Resistance Blows/Ft. N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max. Size. In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med. Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
1					Damp		SILTY SAND; Brown, fine grained	SM	3/8			Tr	70	20	x	x x x x	x	x	x		x
2													80	25							
3																					
4							SANDSTONE; fine grained, moderate to well sorted. Non-calcareous.														
5																					
6																					
7																					
8							Drilling with rock bit and water with 100% return														
9																					
10																					
1							Drilling feels medium to the driller, approximate drilling rate 2 minutes per foot.														
2																					
3																					
4																					
5																					
6																					
7							Stopped at 14' No groundwater table encountered														
8																					
9																					
20																					
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
30																					

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation No. 9 Job No. 912-1028

Elev. Top of Hole: 7037 Datum: MSL Prepared By: J. Duffield Date: 11/27/79

Type/Size of Boring: 7" Hollow Stem Date: 11/27/79 Driller: T. Kulik Reviewed By: TCA Date: 1/17/80

Depth Ft	Penetration Resistance Blows/Ft C	Penetration Resistance Blows/Ft N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max. Size In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
1					+PL		SANDY CLAY, SOME SILT, TRACE GRAVEL;	CL	1"			Tr	20	60	x	x x		x	x	x	x
2							Reddish Brown, low plasticity						40	80							
3							(embankment fill)														
4																					
5																					
6																					
7																					
8																					
9					+PL		SILTY CLAY, TR. TO SOME SAND, TR.	CL-CH	½"			Tr	10	80	x	x x		x	xx	x	x
10							GRAVEL; Reddish Brown, medium to						20	90							
1							high plasticity (embankment fill)														
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
20																					
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
30																					

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E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 9 (Continued) | Job No. 912-1028

Elev. Top of Hole | Datum | Prepared By: J. Duffield | Date: 11/27/79

Type/Size of Boring: 7" Hollow Stem & NX Core | Date: 11/27/79 | Driller: T. Kulik | Reviewed By | Date

Depth Ft	Penetration Resistance Blows/Ft C	Penetration Resistance Blows/Ft N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Run No.	Max Size in.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
31					+PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH		½"					Tr	10	80	x	x x			x	xx	x	x
2																		20	90						
3																									
4																									
5		50/1"	S																						
6							SANDSTONE; Grey, fine grained, non-calcareous, slightly weathered.			1	1/4														
7											1														
8							Moderately fractured with horizontal		1		3/4		87	40	100%										
9							fractures along bedding planes.				3/4														
40							Very fractured from 37.3' to 38.7'.				1/2														
1							Thin seams (1/16") of clayey				3/4														
2							micaceous materials in some of the				1 1/4														
3							fractures.		2		1 1/2		97	45	100%										
4											2														
5							Very fractured at 45' to 46'				2 1/4														
6											2														
7											1														
8							SANDY CLAY TO CLAYEY SAND; Tr. to				3/4														
9							some sandstone fragments and gravel		3		3/4		20	0	None										
50							size particles (calcareous concre-				1/2														
1		11	S				tions and conglomeritic material),				1/2														
2							Reddish Brown																		
3		14	S																						
4		54/10"	S																						
5							Washed through from 54' to 56'																		
6																									
7							SANDSTONE; Grey, fine grained, non-				3/4														
8							calcareous. Very fractured from				1														
9							56' to 58' and moderately fractured		4		3/4		100	28	None										
60							below 58'. Thin seams of clayey				3/4														
							material at 56.5', 58.3' and 59'.																		
							Coarser below 59.5'.																		

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 9 (Continued) | Job No. 912-1028

Elev. Top of Hole | Datum | Prepared By: J. Duffield | Date: 11/27/79

Type/Size of Boring: NX Core | Date: 11/27/79 | Driller: T. Kulik | Reviewed By | Date

Depth Ft	Penetration Resistance Blows/Ft. C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Run No.	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %
61							SANDSTONE; Grey, fine grained, non-calcareous. Moderately fractured below 58'. Coarser below 59.5'.	1	1 1/4			
2												
3												
4												
5												
6												
7							Stopped at 61'					
8							Groundwater level at 40' on 11/28/79					
9							Pressure tests performed between					
70							36.3' and 45' and between 42.3' and					
1							56'.					
2												
3												
4												
5												
6												
7												
8												
9												
80												
1												
2												
3												
4												
5												
6												
7												
8												
9												
90												

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WATER PRESSURE TESTING IN CORE DRILL HOLES

PROJECT Tsaile Dam Evaluation

HOLE NO. #9 DATE 11/28/79

Test No. 1
Test Pressure 15 PSI
Test Depth From 36.3' To 45'

TIME MIN.	METER READING	WATER GAL.
0	6229.5	--
1	6240.7	11.2
2	6250.6	9.9
3	6257.3	6.7
4	6273.5	16.2
5	6289.1	15.6
6	6306.3	17.2
7	6319.2	12.9
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = 89.7
AVG. TAKE = 12.8 GPM

Test No. 2
Test Pressure 20 (max. pressure obtainable) PSI
Test Depth From 36.3' To 45'

TIME MIN.	METER READING	WATER GAL.
0	6325.9	--
1	6344.8	18.9
2	6367.2	22.4
3	6389.8	22.6
4	6412.6	22.8
5	6435.9	23.3
6	6458.8	22.9
7	6481.8	23.0
8	6505.7	23.9
9	6528.7	23.0
10	6552.4	23.7
11		
12		
13		
14		
15		

TOTAL = 226.5
AVG. TAKE = 22.7 GPM

Test No. 3
Test Pressure 20 PSI
Test Depth From 42.3' To 56'

TIME MIN.	METER READING	WATER GAL.
0	6575.9	--
1	6598.4	22.5
2	6621.5	23.1
3	6646.3	24.8
4	6673.0	26.7
5	6700.5	27.5
6	6729.5	29.0
7	6765.7	36.2
8	6781.4	15.7
9	6802.4	21.0
10	6822.2	19.8
11	6844.2	22.0
12	6864.7	20.5
13	6885.8	21.1
14	6907.0	21.2
15	6929.5	22.5

TOTAL = 353.6
AVG. TAKE = 23.6 GPM

REMARKS Height of water swivel above ground surface was 15.5', while pressure gauge was 5.8' above ground level.

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 10 | Job No. 912-1028

Elev. Top of Hole: 7037 | Datum: MSL | Prepared By: J. Duffield | Date: 12/2/79

Type/Size of Boring: 7" Hollow Stem | Date: 12/2/79 | Driller: T. Kulik | Reviewed By: TCA | Date: 1/18/80

Depth Ft	Penetration Resistance Blows/Ft C	Penetration Resistance Blows/Ft N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Max. Size, In.	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well Med Poor	Grain Shape Angular Subangular Rounded Subrounded	Relative Density Low Med High	Dry Strength None Very Low Low Medium High Very High	Plasticity None Low Medium High	Consistency Soft Firm Stiff Very Stiff Hard	Cementation None Light Moderate Heavy
1					-PL		SANDY CLAY, SOME SILT, TRACE GRAVEL;	CL	1"			Tr	20	60	x	x x		x	x	x	x
2							Reddish Brown, low plasticity						40	80							
3					+PL		(embankment fill)														
4																					
5																					
6																					
7																					
8																					
9					+PL		SILTY CLAY, TR. TO SOME SAND, TR.	CL-CH	½"			Tr	10	80	x	x x		x	xx	x	x
10							GRAVEL; Reddish Brown, medium to						20	90							
1							high plasticity (embankment fill)														
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
20																					
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
30																					

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

E

SOIL BORING DATA

Location of Boring: Tsaile Dam Evaluation | No. 10 (Continued) | Job No. 912-1028

Elev. Top of Hole | Datum | Prepared By: J. Duffield | Date: 12/2/79

Type/Size of Boring: 7" Hollow Stem & NX Core | Date: 12/2/79 | Driller: T. Kulik | Reviewed By | Date

Depth Ft	Penetration Resistance Blows/Ft. C	N	Sample Type	Dry Density pcf	Moisture Content	Graphical Log	Description	Soil Classification	Run No.	Max Size In	Coring Time mins/ft	Drill Water Return	Recovery %	RQD %	Particle Size Distribution % Boulders	Cobbles	Gravel	Sand	Silt & Clay	Gradation Well / Med. / Poor	Grain Shape Angular / Subangular / Rounded / Subrounded	Relative Density Low / Med / High	Dry Strength None / Very Low / Low / Medium / High / Very High	Plasticity None / Low / Medium / High	Consistency Soft / Firm / Stiff / Very Stiff / Hard	Cementation None / Light / Moderate / Heavy
31					+PL		SILTY CLAY, TR. TO SOME SAND, TR. GRAVEL; Reddish Brown, medium to high plasticity (embankment fill)	CL-CH		½"						Tr	10	80	X	X X		X	XX	X	X
40							SANDSTONE; Grey, fine grained, non-calcareous, slightly weathered. Moderately fractured, with mainly horizontal fractures. Vertical fractures at 40.3' to 40.8', 42.7', and 48' to 49'. Thin clayey seams (1/32"-1/16") at 41.7',53.3',53.8'.		1	1 1 1 3/4 3 1/2 2 3/4		75%	83	75									
50									2	2 1 3/4 1 3/4 1 1/2 1 1/2		75%	100	78											
60							Thin coal stringer at 55.3' and traces of coal from 58.5' to 59'		3	2 1/2 2 1/2 1 3/4 1 1/2 1 3/4		50%	100	83											
									4	1 1/2 2 2 1/2 2 2 1/4		50%	95	52											

Stopped at 60'
Groundwater level at 44' on 12/12/79
Pressure test performed from 51' to 60'

NOTE: THE DATA PRESENTED ON THESE BORING LOGS REPRESENTS SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC TEST LOCATIONS AND AT THE TIME DESIGNATED. THIS DATA MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND/OR TIMES. THIS BORING DATA WAS COMPILED PRIMARILY FOR DESIGN PURPOSES. THIS DATA SHOULD NOT BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OR AS DEFINING CONSTRUCTION TECHNIQUES.

WATER PRESSURE TESTING IN CORE DRILL HOLES

PROJECT Tsaile Dam Evaluation

HOLE NO. #10 DATE 12/12/79

Test No. 1
Test Pressure 20+ PSI
Test Depth From 51' To 60'

TIME MIN.	METER READING	WATER GAL.
0	7284.4	--
1	7286.0	1.6
2	7286.2	0.2
3	7287.9	1.7
4	7286.7	-1.2
5	7286.8	0.1
6	7286.9	0.1
7	7287.2	0.3
8	7287.3	0.1
9		
10		
11		
12		
13		
14		
15		

TOTAL = 2.9
AVG. TAKE = 0.4 GPM

Test No. _____
Test Pressure _____ PSI
Test Depth From _____ To _____

TIME MIN.	METER READING	WATER GAL.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = _____
AVG. TAKE = _____ GPM

Test No. _____
Test Pressure _____ PSI
Test Depth From _____ To _____

TIME MIN.	METER READING	WATER GAL.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

TOTAL = _____
AVG. TAKE = _____ GPM

REMARKS Height of water swivel above ground surface was 16', while pressure gauge was 6.4' above ground level.

E

Summary of Pressure Test Results

Boring No.	Test No.	Interval (ft)	Groundwater Table (ft)	Assumed Length of Test Section, L (ft)	Assumed Radius of Hole, r (ft)	Gravity Head, H_g (ft)	Pressure Head, H_p (ft)	Total Head, H_T (ft)	Constant Flow Rate, Q (cu.ft/min)	Permeability, K* (ft/min)	Permeability, K* (cm/sec)
1	1	54.3-65'	39'	10.7'	0.125'	44.3'	23.1'	67.4'	0.0134	1.3×10^{-5}	6.6×10^{-6}
1	2	54.3-65'	39'	10.7'	0.125'	44.3'	69.3'	113.6'	0.0134	7.8×10^{-6}	4.0×10^{-6}
2	1	43-63'	45'	5.0'	0.4'±	50.0'	11.6'	61.6'	1.24	1.6×10^{-3}	8.1×10^{-4}
2	2	43-63'	45'	5.0'	0.4'±	50.0'	23.1'	73.1'	2.09	2.3×10^{-3}	1.2×10^{-3}
2	3	43-63'	45'	5.0'	0.4'±	50.0'	34.7'	84.7'	3.72	3.5×10^{-3}	1.8×10^{-3}
2	4	43-63'	45'	5.0'	0.4'±	50.0'	23.1'	73.1'	3.44	3.8×10^{-3}	1.9×10^{-3}
2	5	43-63'	45'	5.0'	0.4'±	50.0'	11.6'	61.6'	0.03	3.9×10^{-5}	2.0×10^{-5}
4	1	49-58.5'	43'	9.5'	0.2'±	48.3'	34.7'	83.0'	0.134	1.0×10^{-4}	5.1×10^{-5}
5	1	40-49'	41'	9.0'	0.125'	45.5'	23.1'	68.6'	0.92	1.0×10^{-3}	5.1×10^{-4}
5	2	40-49'	41'	9.0'	0.125'	45.5'	46.2'	91.7'	2.23	1.8×10^{-3}	9.1×10^{-4}
6	1	13.5-27'	14'	8.0'	0.3'±	19.5'	23.1'	42.6'	3.09	4.7×10^{-3}	2.4×10^{-3}
7	1	12.5-25'	16'	6.5'	0.3'±	21.3'	11.6'	32.9'	1.30	3.0×10^{-3}	1.5×10^{-3}
7	2	12.5-25'	16'	6.5'	0.3'±	21.3'	23.1'	44.4'	2.74	4.6×10^{-3}	2.3×10^{-3}
7	3	12.5-25'	16'	6.5'	0.3'±	21.3'	27.7'	49.0'	3.77	5.8×10^{-3}	2.9×10^{-3}
9	1	36.3-45'	40'	8.7'	0.125	45.8'	34.7'	80.5'	1.71	1.6×10^{-3}	8.1×10^{-4}
9	2	36.3-45'	40'	8.7'	0.125	45.8'	46.2'	92.0'	3.03	2.6×10^{-3}	1.3×10^{-3}
9	3	42.3-56'	40'	10.0'	0.2'±	45.8'	46.2'	92.0'	3.16	2.1×10^{-3}	1.1×10^{-3}
10	1	51-60'	44'	9.0'	0.125'	50.4'	46.2'	96.6'	0.0535	4.2×10^{-5}	2.1×10^{-5}

$$* \; K = \frac{Q}{2\pi L H_T} \ln \frac{L}{r}$$

APPENDIX B

Laboratory Test Results

Job No. 912-1028

Boring No.	Depth, ft.	Soil Class.	Particle Size Distribution, %				Atterberg Limits			Moisture - Density Rel.			Specific Gravity	Pinhole Dispersion Test			Remarks
			Cobbles 3" to 12"	Gravel 3" to #4	Sand #4 to 200	Fines - 200	PL	LL	PI	Dry Density pcf	Optimum Moisture %	Meth.		Moist. Content %	Dry Density pcf	Classification	
1	10'-12'	CL				75.0*	17	46	29								
1	20'-22'	CL				84.2*	24	44	20								
1	30'-32'	CL				80.8*	17	41	24								
3	5'-7'	CL-CH				85.2*	18	50	32								
3	10'-40'	CH				81.7*	17	53	36	109.8	16.5	5					
3	50'-52'	SP		0	95.3	4.7											
5	5'-6'	CL				52.4*	16	30	14								
5	30'-32'	CH				86.3*	22	56	34								
8	0'-3'	ML		0	47.8	52.2	17	21	4								
Cloth Bag "B"		CH												near PL	see remarks	ND1	samples molded to approx. 95% of max. density by ASTM D698A
Cloth Bag "C"		CH				85.6*	21	52	31					near PL	see remarks	ND2	
Cloth Bag "E"		SC-SM				40.0*	16	23	7					near PL	see remarks	D2	
Cloth Bags "A" &"D" Combined		CL				74.1*	14	22	8	116.5	13.2	5		near PL	see remarks	D2/ND4	

LEGEND

Moisture Density Relationship
1. Tested D-1556/AASHTO T-217
2. Tested ASTMD-2922/D-3017
3. Tested ASTMD-2922/AASHTO T-217
4. Rock correction applied to maximum dry density, AASHTO T-224
5. Other ASTM D698A

Specific Gravity
6. Minus # 4
7. Plus # 4

Classification/Particle Size
8. Visual
9. Laboratory Tested

* minus No. 200 sieve determination only

SOIL PROPERTIES

Job No. 912-1028

Boring No.	Depth, ft.	Soil Class.	Expansion/Compression					Pocket Penetrometer Readings (tsf)	Shear Strength					Consolidation		
			Initial Dry Density pcf	Initial Moisture Content, %	Surcharge KSF	+ Expan. - Comp. %	Max. Swell Pressure KSF		Test Method	Initial Moisture Content, %	Dry Density pcf	C KSF	∅ Deg.	Initial Void Ratio	Surcharge KSF	Consol. %
1	10'-12'	CL						4.2	UC	13.9	115.5	2.33	---			
1	20'-22'	CL						1.25	UC	21.7	107.7	1.11	---			
1	30'-32'	CL						2.75	UC	17.0	114.3	1.17	---			
3	5'-7'	CL-CH						2.1	UC	22.7	103.2	1.19	---			
3	15'-17'	CL-CH						1.5	UC	20.5	109.6	1.36	---			
3	25'-27'	CL-CH						4.5+	UC	12.7	121.4	14.16	---			
5	10'-12'	CH						2.4	UC	24.9	101.0	1.18	---			
5	20'-22'	CH						2.3	UC	23.7	105.5	2.12	---			
5	30'-32'	CH						3.75	UC	19.9	109.0	2.42	---			

LEGEND

Shear Strength Test Method
- DS Direct Shear
- $\underline{DS}$ Direct Shear (saturated)
- $\underline{UC}$ Unconfined Compression
- $\underline{UU}$ Unconsolidated Undrained
- $\overline{CU}$ Consolidated Undrained w/pore press
- $\overline{CU}$ Consolidated Undrained
- CD Consolidated Drained
- CR Cyclic Consolidated Undrained w/pore press

REMARKS

1. In-situ density.
2. Compacted density (Approx. 95% of ASTM:D698 max. density at moisture content slightly below optimum).
3. Compacted density (Approx. 95% of ASTM:D1557 max. density at moisture content slightly below optimum).
4. In-situ moisture.
5. Submerged to approximate saturation.
6. Consolidation % upon saturation.
7.

SOIL PROPERTIES

Tsaile Lake Dam
Job No. 912-1028

TABLE B-1

Summary of Water Content & Dry Density Determinations
On the Undisturbed Samples for Embankment Materials

		Measured Values		ASTM: D698 Values		
Boring No.	Sample Depth (ft)	Dry Density (pcf)	Water Content (%)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	% Compaction
1	10-12	115.5	13.9	109.8	16.5	100+
1	15-16	104.3	18.7	109.8	16.5	95
1	20-22	107.7	21.7	109.8	16.5	98
1	25-26	106.6	21.3	109.8	16.5	97
1	30-32	114.0	17.0	109.8	16.5	100+
1	35-36	105.7	20.1	109.8	16.5	96
3	5-7	103.2	22.7	109.8	16.5	94
3	10-11	96.8	23.9	109.8	16.5	88
3	15-17	109.6	20.5	109.8	16.5	100
3	20-21	---	25.2	109.8	16.5	---
3	25-27	121.4	12.7	109.8	16.5	100+
3	30-31	108.3	12.0	109.8	16.5	99
3	35-36	112.3	14.2	109.8	16.5	100+
3	40-41	---	16.5	109.8	16.5	---
4	37-38	106.9	21.2	109.8	16.5	97
4	40-41	106.9	19.5	109.8	16.5	97
5	5-6	106.0	20.0	116.5	13.2	91
5	10-12	101.0	24.9	109.8	16.5	92
5	15-16	104.7	20.9	109.8	16.5	95
5	20-22	105.5	23.7	109.8	16.5	96
5	25-26	107.4	19.0	109.8	16.5	98
5	30-32	109.0	19.9	109.8	16.5	99
5	35-36	---	12.4	109.8	16.5	---

ENGINEERS TESTING LABORATORIES, INC.

PROJECT TSAILE DAM JOB NO. 912-1028 DATE 11-28-79
TEST TYPE UNCONFINED COMPRESSION
SAMPLE 1 (10-12) DEPTH 10-12
MATERIAL CONDITION UNDISTURBED

LENGTH 6.11 IN. WET WT. 1355.3 GM.
DIAMETER 2.86 IN. DRY WT. 1189.9 GM.
AREA 0.0446 SQ. FT. DRY DENSITY 115.5 PCF
MOISTURE CONTENT 13.9 %

DEFLECTION (IN.)	STRAIN (%)	P. RING READING	LOAD (LBS)	MAJOR PRIN. STRESS(KSF)
0.019	0.3	0.0068	61.0	1.36
0.036	0.6	0.0100	89.8	2.00
0.054	0.9	0.0122	109.5	2.43
0.073	1.2	0.0142	127.5	2.82
0.093	1.5	0.0156	140.0	3.09
0.113	1.8	0.0168	150.8	3.32
0.135	2.2	0.0182	163.4	3.58
0.175	2.9	0.0199	178.6	3.89
0.217	3.6	0.0213	191.2	4.13
0.259	4.2	0.0225	202.0	4.34
0.302	4.9	0.0233	209.2	4.46
0.344	5.6	0.0241	216.3	4.58
0.386	6.3	0.0245	219.9	4.62
0.429	7.0	0.0248	222.6	4.64
0.473	7.7	0.0251	225.3	4.66
0.494	8.1	0.0247	221.7	4.57
0.516	8.4	0.0246	220.8	4.53
0.537	8.8	0.0246	220.8	4.51

Job No.

Lab. No.

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL

Type of Material ☑Undisturbed ☐Remolded ☐Compacted ☐Cyl. ☐Prism

Source of Material Boring Depth

Test Procedure ASTM D2166- Reviewed By Date

Initial Dry Density, pcf

Initial Moisture Content, %

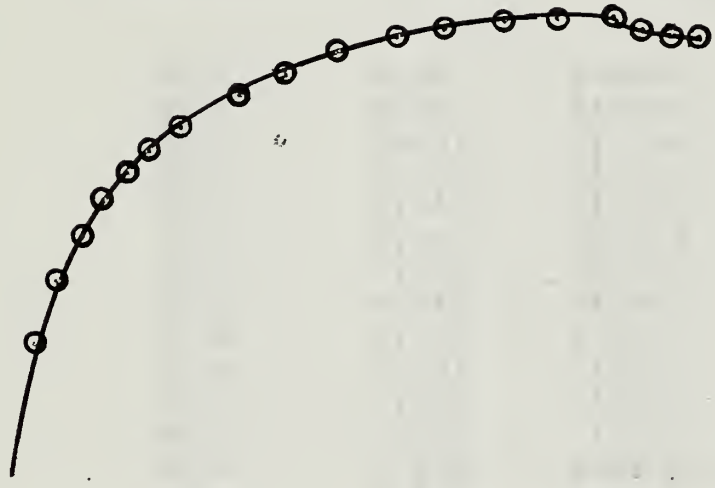
Initial % Saturation

Height/Diameter Ratio

Ave. Strain at Failure, %

Ave. Rate of Strain to Failure, in/min

Unconfined Compressive Strength, KSF



REMARKS

DIAGRAM OF FAILURE



Note: See Reverse Side for Computerized Data

ENGINEERS TESTING LABORATORIES, INC.

PROJECT TSAILE DAM JOB NO. 912-1028 DATE 11-28-79
TEST TYPE UNCONFINED COMPRESSION
SAMPLE 1 (20-22) DEPTH 20-22
MATERIAL CONDITION UNDISTURBED

LENGTH 6.07 IN. WET WT. 1323.1 GM.
DIAMETER 2.84 IN. DRY WT. 1087.2 GM.
AREA 0.0440 SQ. FT. DRY DENSITY 107.7 PCF
MOISTURE CONTENT 21.7 %

DEFLECTION (IN.)	STRAIN (%)	P. RING READING	LOAD (LBS)	MAJOR PRIN. STRESS(KSF)
0.010	0.2	0.0031	27.8	0.63
0.027	0.4	0.0055	49.4	1.12
0.048	0.8	0.0068	61.0	1.38
0.068	1.1	0.0077	69.1	1.55
0.088	1.4	0.0085	76.3	1.71
0.108	1.8	0.0090	80.8	1.80
0.131	2.2	0.0094	84.4	1.88
0.161	2.7	0.0101	90.7	2.01
0.192	3.2	0.0104	93.4	2.06
0.225	3.7	0.0108	96.9	2.12
0.257	4.2	0.0110	98.7	2.15
0.288	4.7	0.0111	99.6	2.16
0.322	5.3	0.0113	101.4	2.18
0.353	5.8	0.0114	102.3	2.19
0.385	6.3	0.0116	104.1	2.22
0.418	6.9	0.0115	103.2	2.19

Job No.

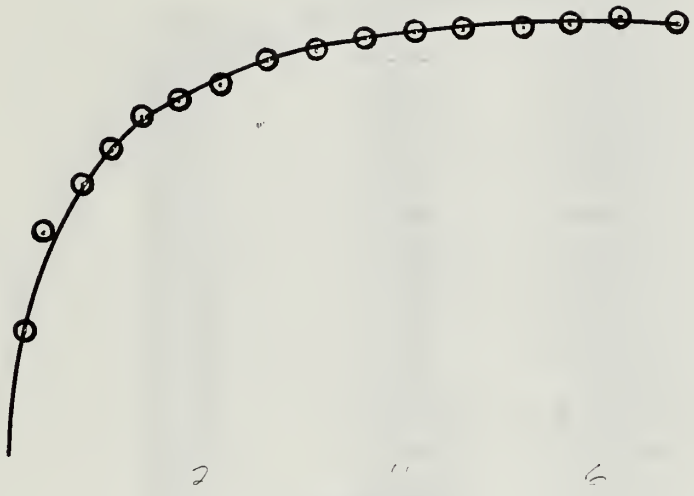
Lab. No.

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL

Type of Material ☒Undisturbed ☐Remolded ☐Compacted ☐Cyl. ☐Prism

Source of Material Boring Depth

Test Procedure ASTM D2166- Reviewed By Date



Initial Dry Density, pcf

Initial Moisture Content, %

Initial % Saturation

Height/Diameter Ratio

Ave. Strain at Failure, %

Ave. Rate of Strain to Failure, in/min

Unconfined Compressive Strength, KSF

REMARKS

DIAGRAM OF FAILURE



Note: See Reverse Side for Computerized Data

ENGINEERS TESTING LABORATORIES, INC.

PROJECT TSAILE DAM JOB NO. 912-1028 DATE 11-28-79
TEST TYPE UNCONFINED COMPRESSION
SAMPLE 1 (30-32) DEPTH 30-32
MATERIAL CONDITION UNDISTURBED

LENGTH 6.02 IN. WET WT. 1348.0 GM.
DIAMETER 2.85 IN. DRY WT. 1152.1 GM.
AREA 0.0443 SQ. FT. DRY DENSITY 114.3 PCF
MOISTURE CONTENT 17.0 %

DEFLECTION (IN.)	STRAIN (%)	P. RING READING	LOAD (LBS)	MAJOR PRIN. STRESS (KSF)
0.019	0.3	0.0052	46.7	1.05
0.038	0.6	0.0069	61.9	1.39
0.057	0.9	0.0082	73.6	1.65
0.076	1.3	0.0090	80.8	1.80
0.096	1.6	0.0095	85.3	1.89
0.116	1.9	0.0101	90.7	2.01
0.136	2.3	0.0104	93.4	2.06
0.177	2.9	0.0110	98.7	2.16
0.217	3.6	0.0113	101.4	2.21
0.259	4.3	0.0117	105.0	2.27
0.301	5.0	0.0120	107.7	2.31
0.343	5.7	0.0121	108.6	2.31
0.383	6.4	0.0123	110.4	2.33
0.425	7.1	0.0124	111.3	2.34
0.446	7.4	0.0123	110.4	2.31

Job No.

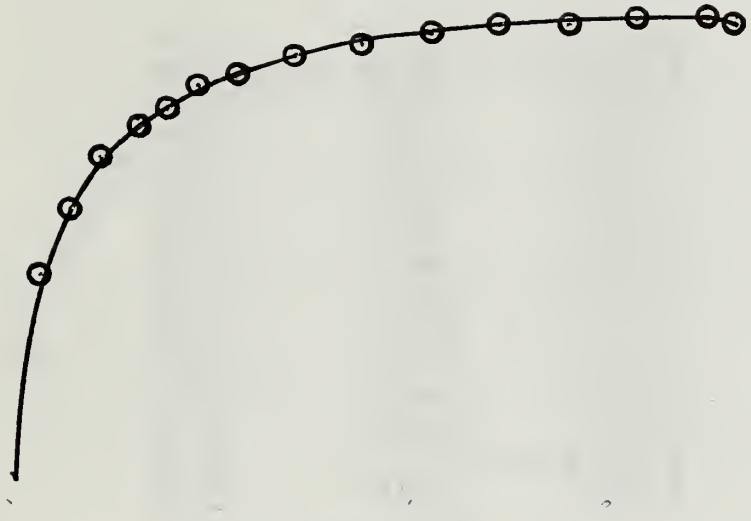
Lab. No.

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL

Type of Material ☐Undisturbed ☐Remolded ☐Compacted ☐Cyl. ☐Prism

Source of Material Boring Depth 30-32

Test Procedure ASTM D2166- Reviewed By Date



Initial Dry Density, pcf	14.3
Initial Moisture Content, %	12.6
Initial % Saturation	
Height/Diameter Ratio	
Ave. Strain at Failure, %	
Ave. Rate of Strain to Failure, in/min	
Unconfined Compressive Strength, KSF	

REMARKS

DIAGRAM OF FAILURE



Note: See Reverse Side for Computerized Data

ENGINEERS TESTING LABORATORIES, INC.

PROJECT TSAILE DAM JOB NO. 912-1028 DATE 11-28-79
TEST TYPE UNCONFINED COMPRESSION
SAMPLE 3 (5-7) DEPTH 5-7
MATERIAL CONDITION UNDISTURBED

LENGTH 6.16 IN. WET WT. 1297.6 GM.
DIAMETER 2.84 IN. DRY WT. 1057.5 GM.
AREA 0.0440 SQ. FT. DRY DENSITY 103.2 PCF
MOISTURE CONTENT 22.7 %

DEFLECTION (IN.)	STRAIN (%)	P. RING READING	LOAD (LBS)	MAJOR PRIN. STRESS (KSF)
0.011	0.2	0.0032	28.7	0.65
0.028	0.5	0.0059	53.0	1.20
0.048	0.8	0.0073	65.5	1.48
0.069	1.1	0.0083	74.5	1.67
0.088	1.4	0.0090	80.8	1.81
0.120	1.9	0.0098	88.0	1.96
0.140	2.3	0.0102	91.6	2.03
0.183	3.0	0.0110	98.7	2.18
0.215	3.5	0.0115	103.2	2.26
0.268	4.4	0.0120	107.7	2.34
0.311	5.0	0.0123	110.4	2.38
0.343	5.6	0.0122	109.5	2.35
0.375	6.1	0.0121	108.6	2.32

Job No.

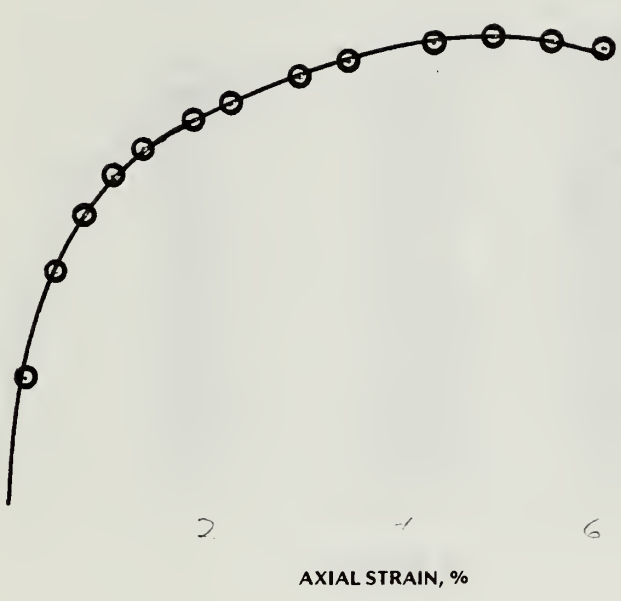
Lab. No.

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL

Type of Material ☐Undisturbed ☐Remolded ☐Compacted ☐Cyl. ☐Prism

Source of Material Boring Depth

Test Procedure ASTM D2166- Reviewed By Date



Initial Dry Density, pcf 103.2

Initial Moisture Content, % 22.0

Initial % Saturation

Height/Diameter Ratio

Ave. Strain at Failure, %

Ave. Rate of Strain to Failure, in/min

Unconfined Compressive Strength, KSF

REMARKS

DIAGRAM OF FAILURE



Note: See Reverse Side for Computerized Data

ENGINEERS TESTING LABORATORIES, INC.

PROJECT TSAILE DAM JOB NO. 912-1028 DATE 11-28-79
TEST TYPE UNCONFINED COMPRESSION
SAMPLE 3 (15-17) DEPTH 15-17
MATERIAL CONDITION UNDISTURBED

LENGTH 6.04 IN. WET WT. 1344.6 GM.
DIAMETER 2.86 IN. DRY WT. 1115.9 GM.
AREA 0.0446 SQ. FT. DRY DENSITY 109.6 PCF
MOISTURE CONTENT 20.5 %

DEFLECTION (IN.)	STRAIN (%)	P. RING READING	LOAD (LBS)	MAJOR PRIN. STRESS (KSF)
0.012	0.2	0.0035	31.4	0.70
0.029	0.5	0.0062	55.7	1.24
0.049	0.8	0.0077	69.1	1.54
0.069	1.1	0.0085	76.3	1.69
0.088	1.5	0.0093	83.5	1.84
0.110	1.8	0.0099	88.9	1.96
0.130	2.2	0.0104	93.4	2.05
0.161	2.7	0.0110	98.7	2.15
0.193	3.2	0.0116	104.1	2.26
0.224	3.7	0.0123	110.4	2.38
0.257	4.3	0.0128	114.9	2.47
0.288	4.8	0.0133	119.4	2.55
0.320	5.3	0.0135	121.2	2.57
0.353	5.8	0.0139	124.8	2.63
0.384	6.4	0.0143	128.4	2.69
0.417	6.9	0.0145	130.2	2.72
0.450	7.5	0.0146	131.1	2.72
0.481	8.0	0.0146	131.1	2.70

Job No.

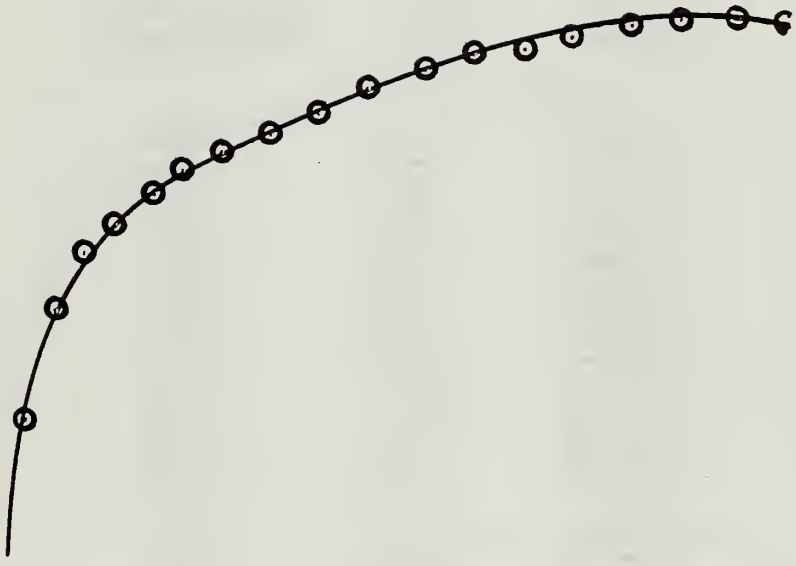
Lab. No.

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL

Type of Material ☐Undisturbed ☐Remolded ☐Compacted ☐Cyl. ☐Prism

Source of Material Boring Depth

Test Procedure ASTM D2166- Reviewed By Date



Initial Dry Density, pcf

Initial Moisture Content, %

Initial % Saturation

Height/Diameter Ratio

Ave. Strain at Failure, %

Ave. Rate of Strain to Failure, in/min

Unconfined Compressive Strength, KSF

REMARKS

DIAGRAM OF FAILURE



Note: See Reverse Side for Computerized Data

ENGINEERS TESTING LABORATORIES, INC.

PROJECT TSAILE DAM JOB NO. 912-1028 DATE 11-28-79
TEST TYPE UNCONFINED COMPRESSION
SAMPLE 3 (25-27) DEPTH 25-27
MATERIAL CONDITION UNDISTURBED

LENGTH 6.00 IN. WET WT. 1374.9 GM.
DIAMETER 2.85 IN. DRY WT. 1220.0 GM.
AREA 0.0443 SQ. FT. DRY DENSITY 121.4 PCF
MOISTURE CONTENT 12.7 %

DEFLECTION (IN.)	STRAIN (%)	P. RING READING	LOAD (LBS)	MAJOR PRIN. STRESS(KSF)
0.002	0.0	0.0045	40.4	0.91
0.007	0.1	0.0160	143.6	3.24
0.009	0.2	0.0214	192.1	4.33
0.015	0.3	0.0322	289.0	6.51
0.020	0.3	0.0442	396.8	8.93
0.027	0.5	0.0547	491.0	11.03
0.035	0.6	0.0644	608.5	13.66
0.044	0.7	0.0724	787.5	17.64
0.056	0.9	0.0800	957.5	21.41
0.080	1.3	0.0844	1055.9	23.52
0.104	1.7	0.0875	1125.3	24.96
0.130	2.2	0.0904	1190.2	26.28
0.157	2.6	0.0925	1237.1	27.19
0.184	3.1	0.0941	1272.9	27.85
0.212	3.5	0.0952	1297.5	28.25
0.240	4.0	0.0956	1306.5	28.31
0.271	4.5	0.0952	1297.5	27.97
0.302	5.0	0.0937	1264.0	27.10
0.333	5.6	0.0906	1194.6	25.47

Job No.

Lab. No.

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL

Type of Material ☐Undisturbed ☐Remolded ☐Compacted ☐Cyl. ☐Prism

Source of Material Boring Depth

Test Procedure ASTM D2166- Reviewed By Date



Initial Dry Density, pcf

Initial Moisture Content, %

Initial % Saturation

Height/Diameter Ratio

Ave. Strain at Failure, %

Ave. Rate of Strain to Failure, in/min

Unconfined Compressive Strength, KSF

REMARKS

DIAGRAM OF FAILURE



Note: See Reverse Side for Computerized Data

ENGINEERS TESTING LABORATORIES, INC.

PROJECT TSAILE DAM JOB NO. 912-1028 DATE 1-4-80
TEST TYPE UNCONFINED COMPRESSION
SAMPLE 5 (10-12) DEPTH 10-12
MATERIAL CONDITION UNDISTURBED

LENGTH 6.38 IN. WET WT. 1347.5 GM.
DIAMETER 2.85 IN. DRY WT. 1078.9 GM.
AREA 0.0443 SQ. FT. DRY DENSITY 101.0 PCF
MOISTURE CONTENT 24.9 %

DEFLECTION (IN.)	STRAIN (%)	P. RING READING	LOAD (LBS)	MAJOR PRIN. STRESS (KSF)
0.010	0.2	0.0024	21.5	0.49
0.036	0.6	0.0053	47.6	1.07
0.074	1.2	0.0080	71.8	1.60
0.111	1.7	0.0095	85.3	1.89
0.153	2.4	0.0106	95.2	2.10
0.192	3.0	0.0111	99.6	2.18
0.232	3.6	0.0115	103.2	2.25
0.275	4.3	0.0119	106.8	2.31
0.316	5.0	0.0122	109.5	2.35
0.357	5.6	0.0122	109.5	2.33
0.398	6.2	0.0124	111.3	2.36
0.440	6.9	0.0123	110.4	2.32

Job No.

Lab. No.

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL

Type of Material ☐Undisturbed ☐Remolded ☐Compacted ☐Cyl. ☐Prism

Source of Material Boring 5 Depth 10-12

Test Procedure ASTM D2166- Reviewed By Date



Initial Dry Density, pcf 101.0

Initial Moisture Content, % 14.7

Initial % Saturation

Height/Diameter Ratio 2.2:1

Ave. Strain at Failure, %

Ave. Rate of Strain to Failure, in/min

Unconfined Compressive Strength, KSF

REMARKS

DIAGRAM OF FAILURE

Note: See Reverse Side for Computerized Data

ENGINEERS TESTING LABORATORIES, INC.

PROJECT TSAILE DAM JOB NO. 912-1028 DATE 1-4-80
TEST TYPE UNCONFINED COMPRESSION
SAMPLE 5 (20-22) DEPTH 20-22
MATERIAL CONDITION UNDISTURBED

LENGTH 6.04 IN. WET WT. 1320.1 GM.
DIAMETER 2.85 IN. DRY WT. 1067.2 GM.
AREA 0.0443 SQ. FT. DRY DENSITY 105.5 PCF
MOISTURE CONTENT 23.7 %

DEFLECTION (IN.)	STRAIN (%)	P. RING READING	LOAD (LBS)	MAJOR PRIN. STRESS(KSF)
0.016	0.3	0.0028	25.1	0.57
0.031	0.5	0.0070	62.8	1.41
0.053	0.9	0.0130	116.7	2.61
0.078	1.3	0.0156	140.0	3.12
0.107	1.8	0.0174	156.2	3.46
0.145	2.4	0.0189	169.7	3.74
0.184	3.0	0.0197	176.8	3.87
0.224	3.7	0.0205	184.0	4.00
0.265	4.4	0.0214	192.1	4.15
0.307	5.1	0.0217	194.8	4.17
0.347	5.7	0.0222	199.3	4.24
0.389	6.4	0.0223	200.2	4.23
0.430	7.1	0.0225	202.0	4.23
0.470	7.8	0.0225	202.0	4.20

Job No.

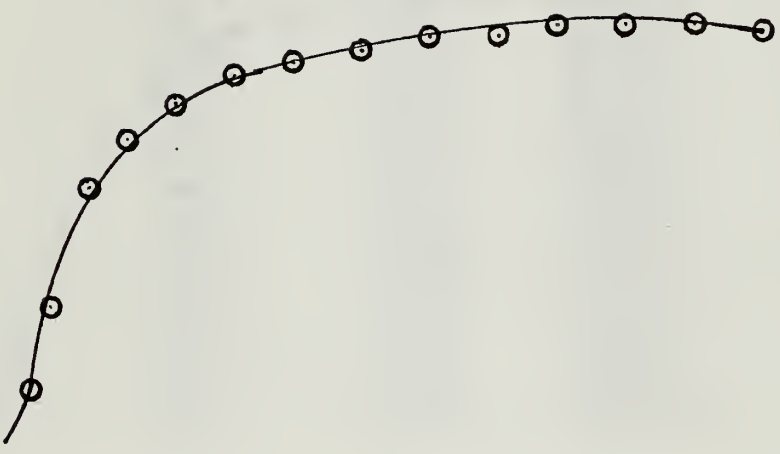
Lab. No.

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL

Type of Material ☑Undisturbed ☐Remolded ☐Compacted ☐Cyl. ☐Prism

Source of Material Boring Depth

Test Procedure ASTM D2166- Reviewed By Date



Initial Dry Density, pcf

Initial Moisture Content, %

Initial % Saturation

Height/Diameter Ratio

Ave. Strain at Failure, %

Ave. Rate of Strain to Failure, in/min

Unconfined Compressive Strength, KSF

REMARKS

DIAGRAM OF FAILURE

Note: See Reverse Side for Computerized Data

ENGINEERS TESTING LABORATORIES, INC.

PROJECT TSAILE DAM JOB NO. 912-1028 DATE 1-4-80
TEST TYPE UNCONFINED COMPRESSION
SAMPLE 5 (30-32) DEPTH 30-32
MATERIAL CONDITION UNDISTURBED

LENGTH 6.17 IN. WET WT. 1349.9 GM.
DIAMETER 2.85 IN. DRY WT. 1125.9 GM.
AREA 0.0443 SQ. FT. DRY DENSITY 109.0 PCF
MOISTURE CONTENT 19.9 %

DEFLECTION (IN.)	STRAIN (%)	P. RING READING	LOAD (LBS)	MAJOR PRIN. STRESS (KSF)
0.016	0.3	0.0060	53.9	1.21
0.043	0.7	0.0103	92.5	2.07
0.078	1.3	0.0141	126.6	2.82
0.117	1.9	0.0164	147.2	3.26
0.158	2.6	0.0180	161.6	3.55
0.197	3.2	0.0193	173.2	3.79
0.238	3.9	0.0206	184.9	4.01
0.279	4.5	0.0215	193.0	4.16
0.321	5.2	0.0224	201.1	4.30
0.362	5.9	0.0230	206.5	4.39
0.404	6.5	0.0237	212.7	4.49
0.445	7.2	0.0243	218.1	4.57
0.496	8.0	0.0247	221.7	4.60
0.549	8.9	0.0255	228.9	4.71
0.611	9.9	0.0262	235.2	4.78
0.663	10.7	0.0265	237.9	4.79
0.714	11.6	0.0270	242.4	4.84

Job No.

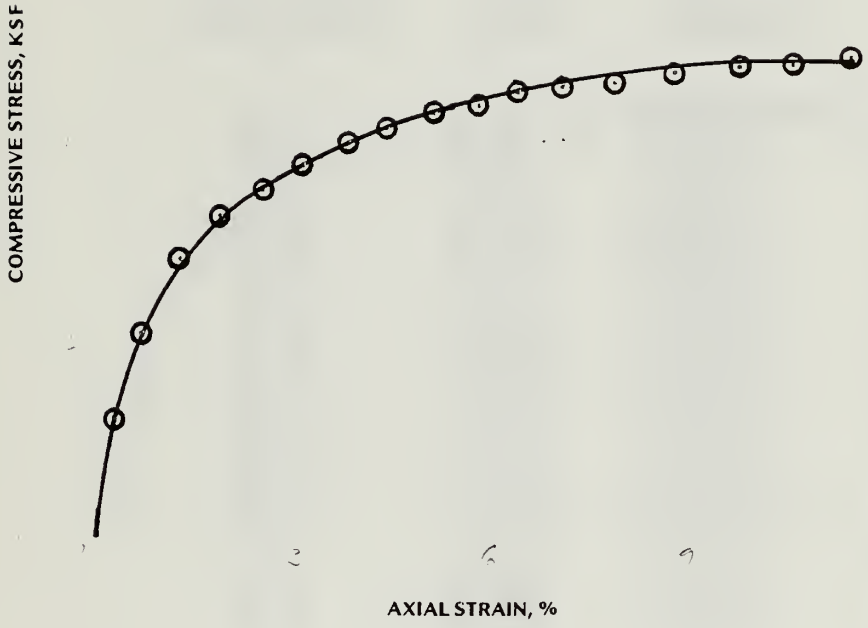
Lab. No.

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL

Type of Material ☒Undisturbed ☐Remolded ☐Compacted ☐Cyl. ☐Prism

Source of Material Boring Depth

Test Procedure ASTM D2166- Reviewed By Date



Initial Dry Density, pcf

Initial Moisture Content, %

Initial % Saturation

Height/Diameter Ratio

Ave. Strain at Failure, %

Ave. Rate of Strain to Failure, in/min

Unconfined Compressive Strength, KSF

REMARKS

DIAGRAM OF FAILURE

Note: See Reverse Side for Computerized Data

APPENDIX C

Stability Analysis

INTERNAL WORK SHEETS

Project/Subject Tsaile Dam — Job. No. 912-1028

Date 1/24/80 Sheet 1 of 4

Simplified Stability Analysis — By TCA

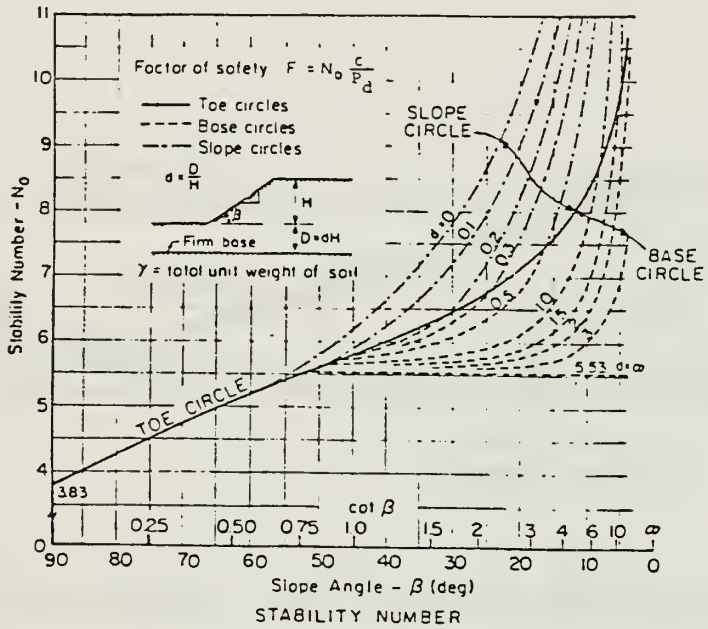
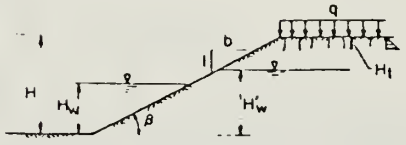


Fig. 6 SLOPE STABILITY CHARTS FOR $\phi = 0$ SOILS (after Jonbu, 1968)



$$P_d = \frac{\gamma H + q - \gamma_w H_w}{\mu_q \mu_w \mu_t}$$

$$P_e = \frac{\gamma H + q - \gamma_w H'_w}{\mu_q \mu'_w}$$

(In formula for P_e take $q = 0$, $\mu_q = 1$ for unconsolidated condition)

REDUCTION FACTORS FOR SUBMERGENCE (μ_w) AND SEEPAGE (μ'_w)

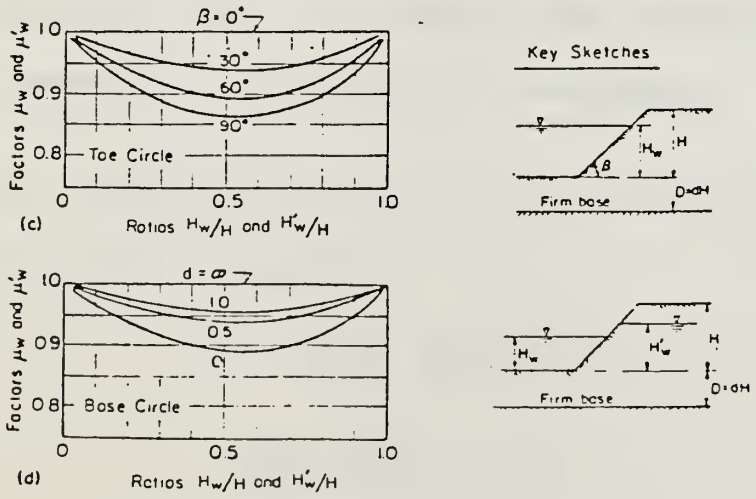


Fig. 7 REDUCTION FACTORS FOR SLOPE STABILITY CHARTS FOR $\phi = 0$ AND $\phi > 0$ SOILS (after Jonbu, 1968)

Assumptions:

Surcharge

$q = 0$; $\mu_q = 1.0$

Tension Crack

$\mu_t = 1.0$, $H_t = 0$

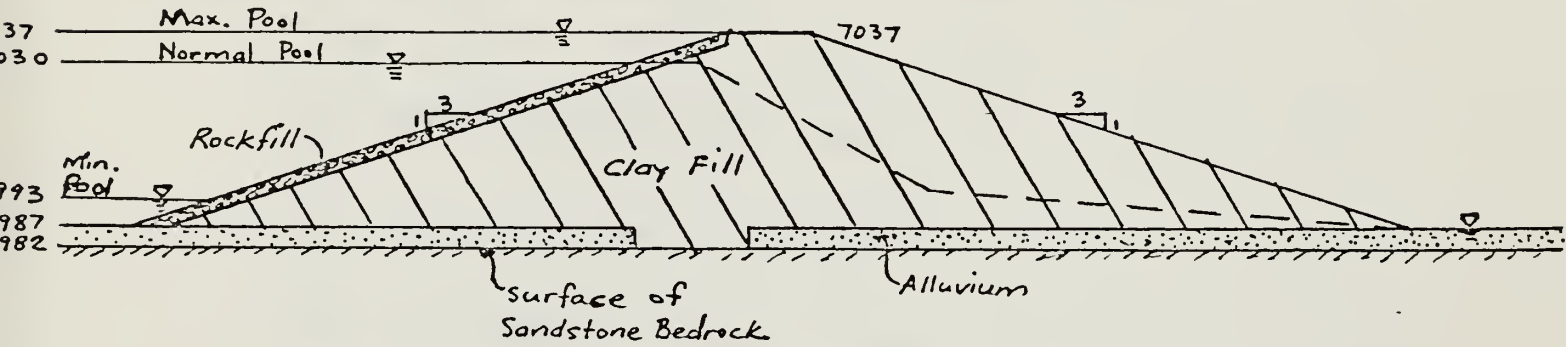
Slope Stability Charts (Reference 5)

INTERNAL WORK SHEETS

Project/Subject Tsaile Dam — Job. No. 912-1028

Date 1/24/80 Sheet 2 of 4

By TCA



Assumptions for Simplified Stability Analysis:

1) Embankment and underlying alluvium assumed to be homogenous.

use $\gamma_T = 130$ pcf, $\phi = 0°$ and $c_{av.} = 1200$ psf

2) Maximum pool level exists for relatively short duration, i.e. not long enough to fully saturate embankment.

3) For both the upstream and downstream slopes,

$$d = \frac{D}{H}$$

where $H = 50'$ and $D = 5'$

$$d = 5/50 = 0.1$$

and $\cot \beta = 3.0$

INTERNAL WORK SHEETS

Project/Subject Tsaile Dam Job. No. 912-1028

Date 1/24/80 Sheet 3 of 4

By TCA

A. Upstream Slope $\gamma_r = 130$ pcf, $\phi = 0°$ and $c_{av} = 1200$ psf

$H = 50'$, $d = 0.1$, $\cot\beta = 3.0$

1.) Normal Pod Condition $H_w = 7030 - 6987 = 43'$

$H_w/H = 43'/50' = 0.86 \longrightarrow \mu_w = 0.95$

$$P_d = \frac{130 \times 50' + 0 - 62.5 \times 43'}{0.95} = 4013.2 \text{ psf}$$

$N_0 = 9.7$ for $d = 0.1$ and $\cot\beta = 3$

$$F.S. = 9.7 \times \frac{1200}{4013.2} = 2.90 \quad \underline{OK}$$

2.) Sudden Drawdown from Normal to Minimum Pool

$H_w = 6993 - 6987 = 6'$, $H_w/H = 6/50 = 0.12 \longrightarrow \mu_w = 0.97$

$$P_d = \frac{130 \times 50 + 0 - 62.5 \times 6'}{0.97} = 6314.4 \text{ psf}$$

$N_0 = 9.7$ for $d = 0.1$ and $\cot\beta = 3$

$$F.S. = 9.7 \times \frac{1200}{6314.4} = 1.84 \quad \underline{OK}$$

B. Downstream Slope $\gamma_r = 130$ pcf, $\phi = 0°$ and $c_{av} = 1200$ psf

$H = 50'$, $d = 0.1$, $\cot\beta = 3.0$

$H_w = 0' \longrightarrow H_w/H = 0 \longrightarrow \mu_w = 1.0$

$$P_d = \frac{130 \times 50 + 0 - 62.5 \times 0}{1.0} = 6500 \text{ psf}$$

$N_0 = 9.7$ for $d = 0.1$ and $\cot\beta = 3$

$$F.S. = 9.7 \times \frac{1200}{6500} = 1.79 \quad \underline{OK}$$

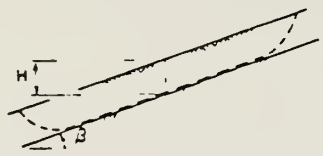
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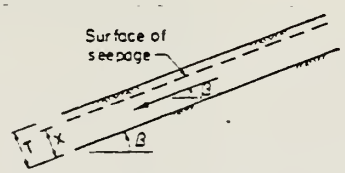
INTERNAL WORK SHEETS

Project/Subject Tsaile Dam — Job. No. 912-1028

Infinite Slope Analysis for Upstream Rockfill Slope Zone — Date 1/24/80 Sheet 4 of 4

By TCA





Seepage parallel to slope

$r_u = \frac{X}{T}\frac{\gamma_w}{\gamma}\cos^2\beta$

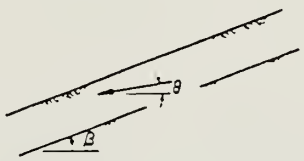
γ = total unit weight of soil

γ_w = unit weight of water

c' = cohesion intercept, ϕ' = friction angle } Effective Stress

r_u = pore pressure ratio = $\frac{u}{\gamma H}$

u = pore pressure at depth H



Seepage emerging from slope

$r_u = \frac{\gamma_w}{\gamma}\frac{1}{1+\tan\beta\tan\theta}$

(From Reference 5)

Steps:

① Determine r_u from measured pore pressures or formulas at right

② Determine A and B from charts below

③ Calculate $F = A\frac{\tan\phi'}{\tan\beta} + B\frac{c'}{\gamma H}$

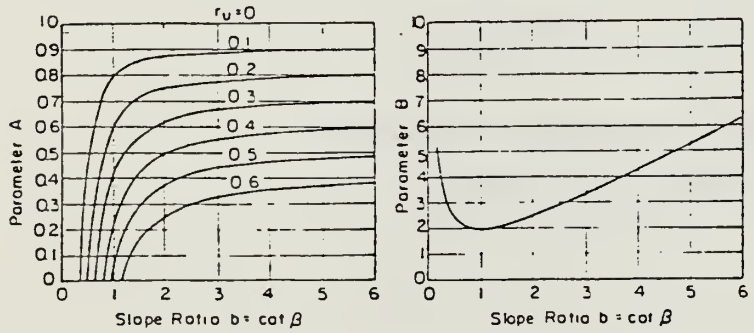


Fig 10 STABILITY CHARTS FOR INFINITE SLOPES

Assumptions for Rockfill Zone: $\gamma_T = 125$ pcf, $\phi = 40°$, $c = 0$

For condition of sudden drawdown, consider seepage emerging from slope. $\beta = 18.4°$ ($\cot\beta = 3.0$) and θ assumed to be about 15°.

$$r_u = \frac{62.5}{125} \times \frac{1}{1 + \tan 18.4° \tan 15°} = 0.46 \rightarrow A = 0.49$$

$$F.S. = 0.49\,\frac{\tan 40°}{\tan 18.4°} = 1.24$$ OK, considering the conservative nature of the analysis.

E

APPENDIX D

Proposed Grouting Program
& Guide Specifications

Proposed Grouting Program

A. Along Each Abutment Contact

A line of grout holes (combination compaction and curtain grouting) is proposed at 5' spacing along each abutment contact. Estimate total of 31 holes along each contact with an average depth of 40'. Each hole will involve an approximately 20' grout zone. Estimate moderately high grout take (5.0 cu. ft. per ft.) for half of the zone and a moderate take (2.0 cu. ft. per ft.) for remainder of 20' zone.

Estimated drilling footage 2 x 31 holes x 40' per hole = 2480 lin.ft.
Estimated grout take 2 x 31 holes x (10 x 5 + 10 x 2) = 4340 cu.ft. or 161 cu.yd.

B. Curtain Grout Holes Along Longitudinal Centerline of Dam

A line of curtain grout holes is proposed extending along longitudinal centerline of dam from each abutment contact for a distance of 100 feet.

South Abutment	10 holes spaced at 10' o.c.
North Abutment	6 holes spaced at 10' to 20' o.c. (See Figure 4)
Extra Holes	4 holes estimated

The average depth of these holes is estimated to be 60' with a 20' grout zone in each hole. Estimate moderately high grout take (5.0 cu. ft. per ft.) for half of 20' zone and a moderate take (2.0 cu. ft. per ft.) for remainder of zone.

Estimated drilling footage 20 holes x 60' = 1200 lin.ft.
Estimated grout take 20 holes x (10 x 5 + 10 x 2) = 1400 cu.ft. or 52 cu.yd.

Estimated Totals

Drilling footage = 2480 +1200 = 3680 lin.ft.
Grout take = 161 + 52 = 213 cu.yd.

Guide Specifications for Proposed Grouting Program

I. Scope of Work

The work covered by this section consists of furnishing all supervision, labor, materials, and equipment, and performing all operations in connection with sealing of openings in the soil and rock underlying dam embankment by injection of grout as shown on the plans or as described herein.

II. General

A. Grout shall consist of a mixture of portland cement, and water, with or without sand or other bulk fillers, together with such admixtures as may be necessary or desirable to accomplish the intent of these specifications.

B. Foundation Stabilization shall consist of injection under pressure of grout with or without the use of a primer solution, at such location, at such depths, and at such pressures as may be necessary to fill openings within pervious rock abutments as well as to fill voids within soil wherever possible. The placement of grout within the soil zones beneath rock abutment overhang areas shall act to compress and compact surrounding soil in such a way that existing seepage paths are greatly reduced or eliminated.

C. The contractor shall furnish records of past successful experience in performing this type of work. The contractor shall submit to the Engineer for approval a description of the materials to be used and the proposed methods of operation, and furnish records and data to demonstrate that the completed work will satisfy the requirements of these specifications.

III. Materials

A. Portland Cement shall conform to Federal Specification SS-C-192 for "Cements; Portland", or current A.S.T.M.

Standards, designation C-150.

B. Alfesil shall be the pozzolanic material sold by Concrete Chemicals Company of Cleveland, Ohio or equal. It shall be a finely powdered material, composed essentially of compounds of amorphous silica, alumina, and iron, which possesses the property of combining with lime liberated during the process of hydration of portland cement, and shall conform to Corps of Engineers Specification CRC C-262.

C. Intrusion Aid shall be the grout fluidifier manufactured by Concrete Chemicals Company of Cleveland, Ohio or equal. It shall inhibit early stiffening, decrease bleeding, eliminate setting shrinkage, increase fluidity, produce the effect of an air entraining agent with respect to freezing and thawing, and shall otherwise conform to Corps of Engineers Specification CRD C-566.

D. Water shall be fresh, clean, and free from injurious amounts of sewage, oil, acid, alkali, salts or organic matter.

E. Fine Aggregate or bulk fillers shall consist of sand, silt, clay or a combination of these materials so selected as to fulfill the requirements of Section II B of these specifications.

F. Chemix Admixtures, if used, shall be similar or equal to the product manufactured by Concrete Chemicals Company of Cleveland, Ohio. It shall be an integral lubricating agent which acts to control consistency, penetration, pumping pressures, bleeding, stiffening rate and setting time.

G. Other Admixtures shall not be used without prior written approval of the Engineer.

H. Grout Primer, if used, shall be a low viscosity liquid which acts to lubricate passages in soil or rock preparatory to injection of cement base grout. It shall contain a surfactant, together with chemicals which react with this surfactant to produce an impermeable gel. It shall be so proportioned that gel formation takes place not less than 30 minutes after mixing. The grout primer shall be Terra Firma, as manufactured by Concrete Chemicals Company of Cleveland, Ohio, or equal.

IV. Placing Injection Points

In general, the split spacing method of injection point location shall be used in which alternate grout holes, shown on the grouting plan drawing, are grouted first. After grout injection at these points has been completed, interjacent holes, located midway between the initial alternate holes, shall be grouted. Further splitting of injection point spacing may be required depending on results obtained in previous grouting operations.

All planned grout holes shall be extended to elevation 6980. Depth of additional injection points shall be dependent on results obtained at previous locations.

In pervious rock, holes shall be rotary drilled with a "plugged" bit in a manner which will not unnecessarily damage the structure of or plug voids in the rock. In soils or unconsolidated materials, injection points may be driven, drilled, or jetted in place but the method of placement shall not unnecessarily disturb soil structure, as by consolidation or plugging voids, in such a way as to reduce grout quantities or permit undesirable relief of grouting pressure at the interface of soil and injection pipes. All grout holes extending through the dam shall be cased to the top of rock, in order to eliminate the possiblity of hydraulic fracturing of the earth embankment.

Diameter of injection pipes or drill holes shall be adequate to permit injection of the most viscous mix anticipated without undue loss of head due to hydraulic friction, but in no case shall be less than EX drill hole or 3/4" pipe.

For all types of injection points, accurate installation records shall be kept including location and depth of injection points, method of installation and other pertinent data such as water loss during rotary drilling, difficulties encountered during drilling or pipe driving, and blow count data if hand pipe drivers are used.

V. Grout Injection Procedures

The stage grouting method shall be used for grouting on rock. The maximum stage interval shall be 5 feet. Each stage shall be drilled and washed. A packer shall then be set within the bottom of the casing and the stage pressure tested with water. If the water testing indicates a significant take, then the stage shall be grouted until the take is less than 1.0 cu. ft. in 10 minutes. After the grout has attained its initial set, the hole will then be cleaned out or redrilled and the sequence of operations repeated at the next lower stage. Injection pressure shall be determined by grout consumption and foundation conditions but shall in no case be great enough to cause heaving of surrounding soil or rock. In no case should the pressure at the top of the hole exceed one psi per foot of cover above the packer.

A primer or lubricating solution may be injected in advance of portland cement base grout to reduce injection pressure required or to increase grout take.

When grout injection is proceeding near surface level, pressure shall be lowered and measures taken to minimize or control uplift of the structural foundation. Where surface leaks occur, efforts should be made to caulk the surface openings with wood wedges,

oakum, etc. If leaks are inaccessible or cannot be caulked, they should be stopped by grouting with a thick grout mix.

Accurate records shall be kept of grout mix proportions, quantities at each location and injection pressures. The actual sequence of grouting operations, proportioning of grout mixes, etc., will be as herein provided, except that these provisions may be modified by the Engineer as required by field conditions.

VI. Equipment

Only approved mixing and pumping equipment shall be used in the preparation and handling of grout. All oil or other rust inhibitors shall be removed from the mixing drums, stirring mechanisms, and other portions of the equipment in contact with the grout before the mixers are used. All equipment shall be maintained in first class operating condition at all times and shall include, but not be limited to, the following items:

A. Specially equipped grout pump capable of operating at a maximum discharge pressure as required by site conditions.

B. A power operated grout mixer specifically designed for the proper mixing of pumpable slurry, together with a mechanically agitated pump, if necessary, to maintain uninterrupted grout supply.

C. Valves, pressure gages, pressure hose, supply lines and small tools as may be necessary to provide a continuous supply of grout and accurate pressure control.

The capacity of the above listed plant shall be not less than 60 cubic feet of grout per hour when operated at a maximum discharge pressure of 100 psi.

VII. Mix Proportions

All materials shall be accurately measured by volume, weight, or other approved means. Sand or bulk filler shall be added to the

mixture, when, in the opinion of the Engineer, the grout take is such as to warrant its use.

The grout mix proportions shall be adjusted for each point of injection, and from batch to batch during injection, if necessary, to obtain optimum grout take and penetration at minimum pressure, consistent with requirements of Section II B.

APPENDIX E

Hydrologic and Hydraulic Evaluation of Spillway Adequacy

HYDROLOGIC AND HYDRAULIC EVALUATION

OF SPILLWAY ADEQUACY

A. General---------- 1
B. Probable Maximum Precipitation---------- 3
C. Overtopping Potential and Spillway Adequacy---------- 3
Figure 1. Computer Trial Runs for Fitting Spillway Configuration to Required Flow (0.5 PMF)---------- 6
Figure 2. Discharge Coefficients for Vertical-Faced Ogee Crest--------- 7
Input Data---------- 8
Map Showing Area Functions for Computer Input---------- 9
Map Showing Location of Cross Sections---------- 10
Map Showing Isohyetal Patterns---------- 11
Diagram of Computation Program---------- 12
Computation of Lag Time---------- 13
Computations for Determining Probable Maximum Precipitation--------- 14
Computations for Local Storm---------- 15
Computations for General Storm---------- 16
Summary Analysis of Data---------- 17
Run 1---------- 18
Run 2---------- 19
Run 3---------- 20
Run 4---------- 21
Run 5---------- 22
Run 6---------- 23
Run 7---------- 24
Run 8---------- 25
Run 9---------- 26
Run 10---------- 27
Run 11---------- 28
Run 12---------- 29
Computer-Derived Plots of Dam Crest Cross Sections----------30-33

HYDROLOGIC AND HYDRAULIC EVALUATION OF SPILLWAY ADEQUACY

A. General

The hydrologic and hydraulic evaluation for spillway adequacy was performed utilizing the January 1979 version of the U. S. Corps of Engineers Hydrologic Engineering Center (HEC) Program HEC-1. This program version incorporates the following:

1. Portions of the Soil Conservation Service (SCS) TR-20A Program to determine a non-dimensional hydrograph and rainfall losses.
2. Portions of previous HEC-1 and HEC-2 programs (in a functional sense) of the U. S. Corps of Engineers for flood routing in channels and over the dam, if overflow occurs. Stream cross-sections and slopes are used as controls on flow depth.

Rainfall data was determined by using techniques and data from the U. S. Weather Bureau publication, *HMR-49*. The weather data, TR-20A non-dimensional hydrograph, and curve numbers (CN) for water losses were assembled for the computation series. All of the collected data are presented in the appendix.

The rating curves for the reservoir were computed by the most recent modification of the HEC-1 program. This was accomplished by including a profile of the top of the dam as part of the computer input. This technique was utilized to perform a series of trial-and-error solutions of various spillway modifications to allow 50 percent of the Probable Maximum Flood (PMF) to flow through a spillway without overtopping.

The drainage areas, cross-section data and reservoir dimensions were taken from U. S. Geological Survey (USGS) 15-minute quadrangle topographic maps. The reservoir dimensions also included data from a topographic map prepared by Lindbergh Engineering, Albuquerque, New Mexico.

Soil characteristics were taken from the SCS publication, *Report and Interpretations for the General Soil Map, Apache County, Arizona.* The interpretative data comes from the SCS *National Engineering Handbook,* Section 4 *(Hydrology).*

One of the major factors in the TR-20A program is the determination of *lag.* Traditionally, this is determined by the equation

$$L = 0.6\ T_C$$

(Eq. 15.3, SCS National Engineering Handbook, Section 4, Hydrology)

The *lag* is the data input to the W2 card of the HEC-1 program. The value of T_C was determined using the equation

$$T_C = \left(\frac{11.9\ L^3}{H}\right)^{.385}$$

This equation is used by the U. S. Bureau of Reclamation (USBR) and others; e.g., *Design of Small Dams,* USBR, p. 67. The value so derived is modified by the river channel routing within the HEC-1 program. The modification is accomplished by the PULS technique. This technique is an option within the HEC-1 program.

The reservoir spillway data and the upper dam configuration were taken from data collected in the field. Topographic considerations of the rough channel

characteristics and the wide channel area required the use of relatively high Manning coefficients. The value 0.06 was used for most of the channel above the dam.

B. Probable Maximum Precipitation

The data for precipitation as an input function are the computed storms taken from *HMR-49*. Two different storms were considered. The first was a general storm for the month of September that included orographic effects. The second was a local storm. Comparing the six-hour general storm and the six-hour local storm it may be seen that the local storm is more severe. The runoff from the general storm was 5.1 inches, while the runoff from the local storm was 6.6 inches. Since the local storm was the more severe, the rainfall for the local storm was used for this analysis.

In general terms, the Probable Maximum Precipitation (PMP) is the theoretically greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin at a particular time of year, as defined by the American Meteorological Society, 1959. The resulting rainfall is much greater than for normal recurrence intervals of 100 or 500 years. For the reservoir at Tsaile Dam, the PMP will cause a flow through the spillway and over the dam of 62,232 cubic feet per second (CFS). The analysis presented here assumed the reservoir had been filled to spillway level by previous rainfall.

C. Overtopping Potential and Spillway Adequacy

Several computer runs were made to fit the relationship of the spillway to the top of the dam. These data are given in Figure 1.

The existing crest and top of the dam were used for the first computer run, with the following results:

RUN No. 1 - Dam is overtopped by 1.55 feet.

The next test was to extend the present spillway width to 200 feet. This resulted in:

RUN No. 2 - Dam is overtopped by 0.90 feet.

Since neither of these considerations prevented overtopping, the dam crest was raised 3.0 feet above the present dam height, and the spillway width was unchanged, with the following results:

RUN No. 3 - Dam is overtopped by 0.09 feet.

Since the dam was still overtopped, the width of the spillway was increased to 125 feet. The result is as follows:

RUN No. 4 - Water surface remains 1.55 feet below top of the dam.

A test was then made for a spillway width of 130 feet:

RUN No. 5 - Water surface remains 1.59 feet below top of the dam.

A test was also made for a spillway width of 160 feet:

RUN No. 6 - Water surface remains 1.8 feet below top of the dam.

And finally, a test was made for a spillway width of 200 feet:

RUN No. 7 - Water surface remains 2.1 feet below top of the dam.

After the completion of the runs to determine the effect of widening the spillway, several tests were made to determine the effect of leaving the top of the dam unchanged at 7037.0 feet while lowering the spillway at widths of 160 feet and 200 feet.

Runs 8, 9 and 10 were made for a spillway 200 feet wide, with successively higher values of elevation for the spillway. The results were as follows:

RUN No. 8 - Spillway Height - 7025.6 feet

Water surface remains 2.01 feet below top of dam.

RUN No. 9 - Spillway height - 7027.6 feet

Water surface remains 0.29 feet below top of dam.

RUN No. 10 - Spillway height of 7028.3 feet

Dam is overtopped by 0.25 feet.

The spillway width of 160 feet was analyzed in Run No. 11, with the result:

RUN No. 11 - Spillway height of 7027.3 feet

Dam is overtopped by 0.19 feet.

The spillway was modified extending its sides as shown in Page 34. The dam crest was also raised three feet, resulting in

RUN No. 12 - Spillway height - 7029.6 feet

Water surface remains 0.66 below top of the dam.

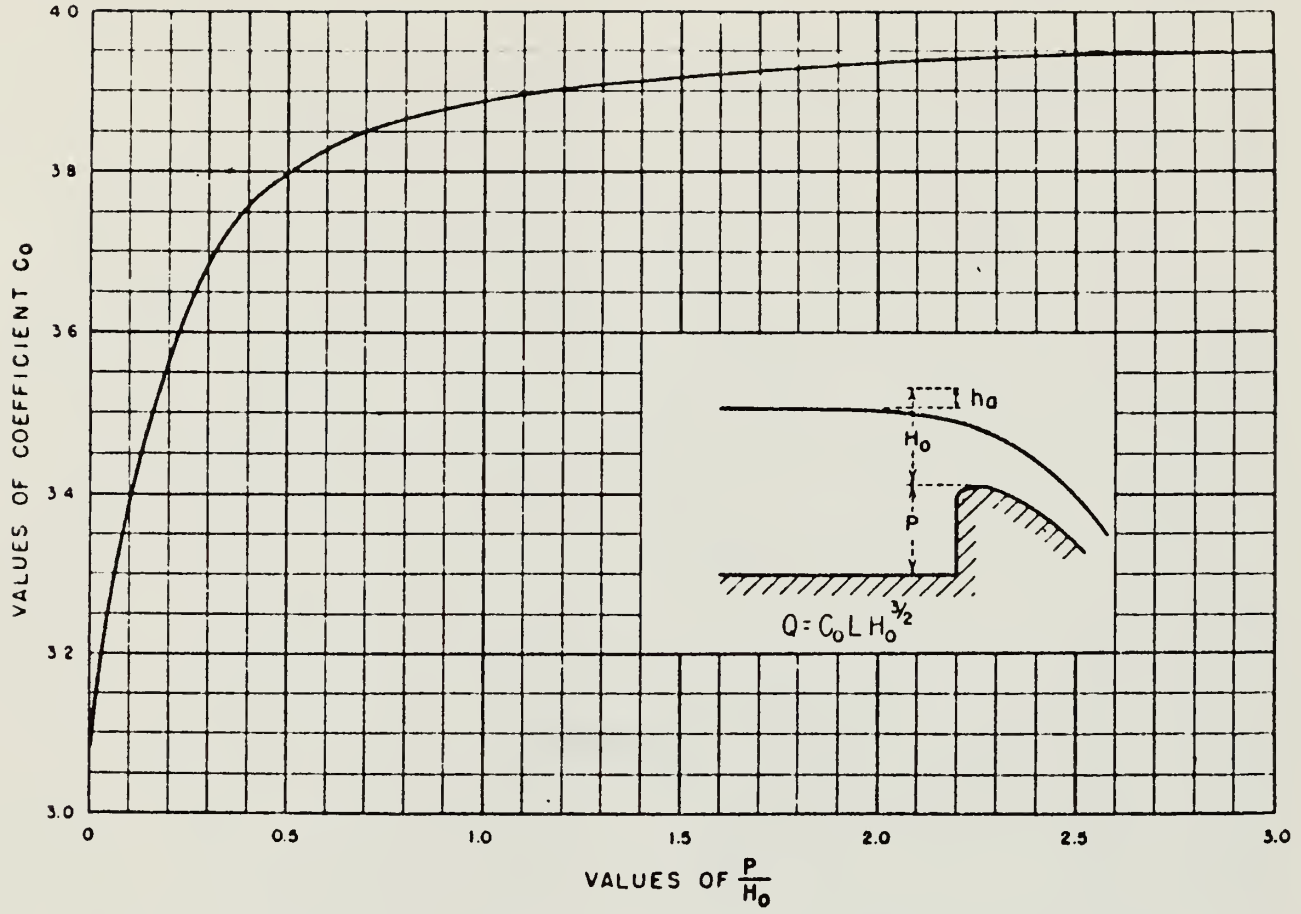
In all cases, the type of spillway utilized was an uncontrolled Ogee. The computations assumed that a ratio of depth of approach to total head of 0.08 will occur. Under these conditions a coefficient of 3.30 was applied directly to the spillway equation of the HEC-1DB program. Data for the coefficient was taken from *Design of Small Dams*, USBR, Figure 249, which is shown as Figure 2 of this report. Design data for the Ogee crest suggested here is also given in *Design of Small Dams*, USBR, pp 372.

COMPUTER TRIAL RUNS FOR FITTING

SPILLWAY CONFIGURATION TO REQUIRED FLOW (0.5 PMF)

Run No.	Elevation of Top of Dam	Elevation Spillway Crest	Spillway Width	Maximum Water Elevation	Depth Over Top of Dam	Safety Margin
1	7037.0'	7029.6'	107'	7038.55'	1.55'	
2	7037.0'	7029.6'	200'	7037.90'	0.90'	
	Adding 3' to Top of Dam, Leaving Spillway Crest the Same					
3	7040.0'	7029.6'	107'	7040.09'	0.09'	
4	7040.0'	7029.6'	125'	7038.45'	0.0	+1.55'
5	7040.0'	7029.6'	130'	7038.41'	0.0	+1.59'
6	7040.0'	7029.6'	160'	7038.20'	0.0	+1.80'
7	7040.0'	7029.6'	200'	7037.90'	0.0	+2.10'
	Lowering Spillway Elevation, Leaving Dam Height the Same					
8	7037.0'	7025.6'	200'	7034.99'	0.0	+2.01'
9	7037.0'	7027.6'	200'	7036.71'	0.0	+0.29'
10	7037.0'	7028.3'	200'	7037.25'	0.25'	
11	7037.0'	7027.3'	160'	7037.19'	0.19'	
	Raising the Dam to 7040.0' and Modifying Spillway Edges					
12	7040.0'	7029.6'	107'	7039.34'	0.0	+0.66'

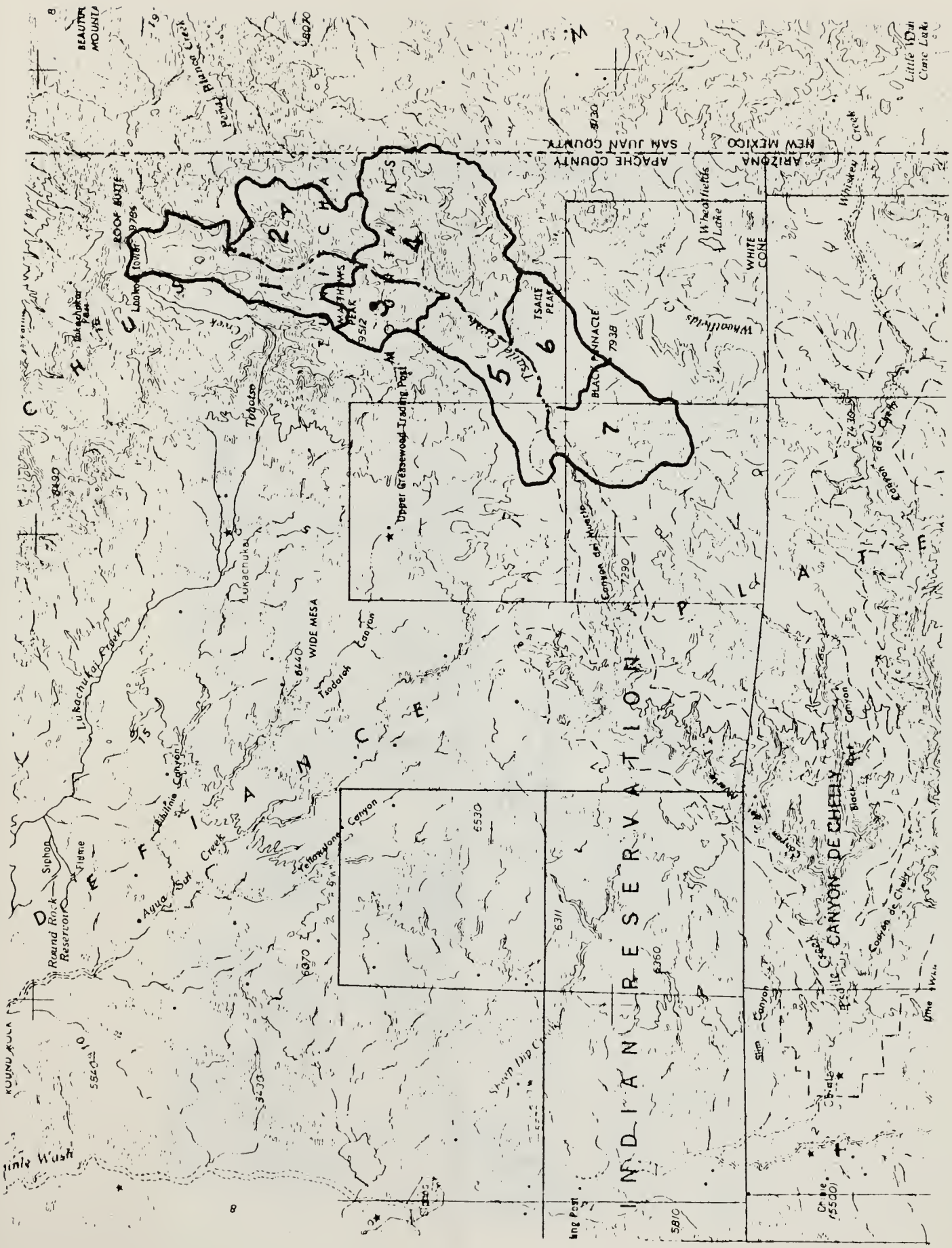
Figure 1. Table showing results of computer trial runs to test overtopping potential and spillway adequacy.



Discharge coefficients for vertical-faced ogee crest.
(*Design of Small Dams, USBR, Figure 249*)

Figure 2

INPUT DATA


ARIZONA
NEW MEXICO
APACHE COUNTY
SAN JUAN COUNTY
CHUSKA MTNS
WIDE MESA
INDIAN RESERVATION
CANYON DE CHELLY
Lukachukai Wash
Round Rock Reservoir
Agua Sal Creek
Tsaile Creek
Tsaile Wash
Upper Greasewood Trading Post
Lukachukai
Tsaile
Whiskey Creek
Wheatfields Lake
WHITE CONE
BLACK MESA
TSAILE PEAK
MOUNTAIN
ROCK BUTTE
Lookout Tower
Buckhorn Pass
Beautiful Mountain
Little Water
Clear Lake
Canyon de Chelly
Black Rock
Spider Rock
Chinle
Sheep Dip Canyon
Tsaile Wash
Lukachukai Ridge
Tsaile Peak
Whitecone
Wheatfields
Tsaile Creek
Whiskey Creek


Roof Butte
Tank
Upper
Wheatfields
Creek
Wheatfields
T U N I T C H A
APACHE
Dam

10
Map Showing Location of Cross Sections


G 1760
F 1200
AREA 7

11
Map Showing Isohyetal Patterns

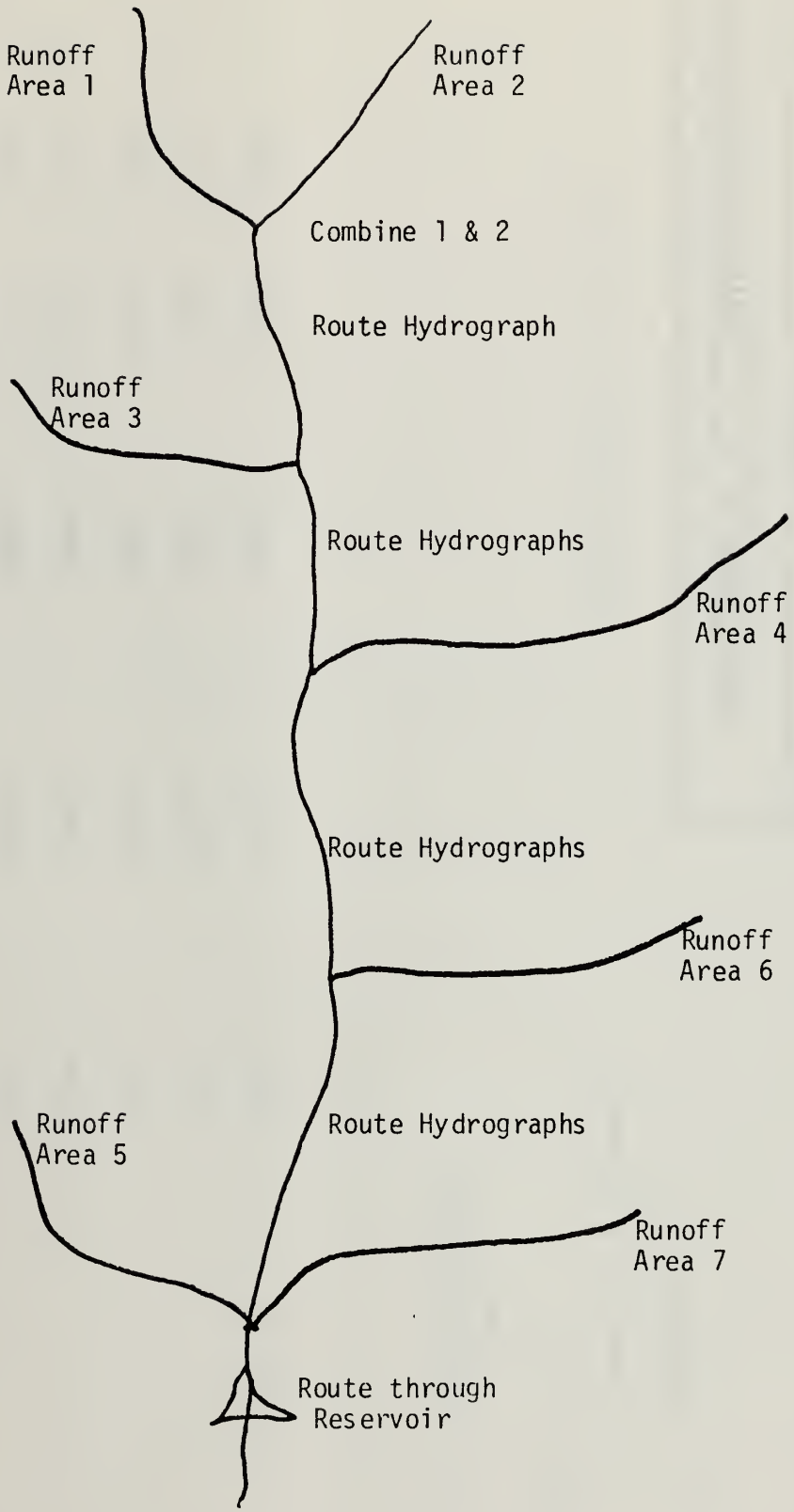


Diagram of Computation Program

Sub-Basin	Slope	Elevation Difference	Distance	T_c	Lag
1	0.13	2200'	17000'	0.51	0.31
2	0.10	1560'	15000'	0.50	0.30
3	0.05	1644'	30000'	1.11	0.68
4	0.04	660'	18000'	0.88	0.53
5	0.06	1440'	23000'	0.86	0.52
6	0.08	1022'	13000'	0.385	0.51
7	0.03	680'	21000'	1.04	0.66

$$L = \frac{\text{Distance (Feet)}}{5280}$$

$$\text{Lag} = 0.6\ T_c$$

H = Elevation Difference

$$T_c = \left(\frac{11.9\ L^3}{H}\right)^{.385}$$

COMPUTATION OF LAG TIME

HYDRAULIC COMPUTATIONS

SCALE:	APPROVED BY:	DRAWN BY
DATE:		REVISED

HYDRO-DATA, INC.

1650 West Alameda Drive, Suite 115
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DRAWING NUMBER

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COMPUTATIONS FOR DETERMINING PROBABLE MAXIMUM PRECIPITATION

HYDRO-DATA, INC.
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P O Box 27334, Tempe, Arizona 85282

.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required. *(HMR-49)*

Drainage TSAILE CREEK & DAM Area 68.6 mi^2
Latitude $36^{o}20'$ Longitude $109^{o}6'$ Minimum Elevation 7000 ft

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.6 in.

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. 90 %

   b. Multiply step 1 by step 2a. 7.7 in.

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.24

	Duration (hr.)									
	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	74	89	95	100	112	118	121	123	125	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	5.7	6.9	7.3	7.7	8.6	9.0	9.3	9.5	9.6	in.
6. Areal reduction [fig. 4.9].	42	48	51	53	60	62.5	65	67	69	%
7. Areal reduced PMP [steps 5 X 6].	2.4	3.3	3.7	4.1	5.2	5.6	6.0	6.4	6.6	in.
8. Incremental PMP [successive subtraction in step 7].				4.1	1.1	0.4	0.4	0.4	0.2	in.
	2.4	0.9	0.4	0.4	} 15-min. increments					
9. Time sequence of incremental PMP according to:										
Hourly increments [table 4.7].					0.4	0.4	4.1	1.1	0.4	0.2	in.
Four largest 15-min. increments [table 4.8].						2.4	0.9	0.4	0.4	in.

HYDRO-DATA, INC.
1650 West Alameda Drive, Suite 115
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P O Box 27334, Tempe, Arizona 85282

.--General-storm PMP computation, Colorado River, Great Basin and California drainages. *(HMR-49)*

Drainage Tsaile Creek & Dam Area 68.6 mi^2

Latitude $36^{o}20'$, Longitude $109^{o}06'$ basin center

Month September

Step		Duration (hrs)						
		6	12	18	24	48	72	
A.	Convergence PMP							
1.	Drainage average value from one of figures 2.5 to 2.16	13.0						in.
2.	Reduction for barrier-elevation [fig. 2.18]	44						%
3.	Barrier-elevation reduced PMP [step 1 X step 2]	5.6						in.
4.	Durational variation [figs. 2.25 to 2.27 and table 2.7].	72	88	95	100	113	118	%
5.	Convergence PMP for indicated durations [steps 3 X 4]	4.12	5.03	5.43	5.72	6.46	6.76	in.
6.	Incremental 10 mi^2 (26 km^2) PMP [successive subtraction in step 5]	4.12	0.82	0.4	0.29	0.74	0.3	in.
7.	Areal reduction [select from figs. 2.28 and 2.29]	86	96	98	99	100	100	%
8.	Areally reduced PMP [step 6 X step 7]	3.54	0.8	0.4	0.3	0.74	0.3	in.
9.	Drainage average PMP [accumulated values of step 8]	3.54	4.34	4.74	5.04	5.78	6.08	in.
B.	Orographic PMP							
1.	Drainage average orographic index from figure 3.11a to d.	5.15						in.
2.	Areal reduction [figure 3.20]	95						%
3.	Adjustment for month [one of figs. 3.12 to 3.17]	100						%
4.	Areally and seasonally adjusted PMP [steps 1 X 2 X 3]	4.9						in.
5.	Durational variation [table 3.6]	33	60	82	100	149	172	%
6.	Orographic PMP for given durations [steps 4 X 5]	1.6	2.9	4.0	4.9	7.3	8.42	in.
C.	Total PMP							
1.	Add steps A9 and B6	5.1	7.3	8.7	10.0	13.1	14.5	%

2. PMP for other durations from smooth curve fitted to plot of computed data.

3. Comparison with local-storm PMP (see sec. 6.3).

SUMMARY ANALYSIS OF DATA

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7029.60	7029.60	7037.00
STORAGE	4822.	4822.	7400.
OUTFLOW	0.	0.	8004.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7034.95	0.00	6605.	4745.	0.00	8.00	0.00
.35	7037.47	.47	7592.	10763.	2.00	7.50	0.00
.50	7038.55	1.55	8049.	22410.	4.00	6.50	0.00
.65	7039.32	2.32	8382.	33368.	4.50	6.50	0.00
.80	7040.02	3.02	8700.	45159.	5.50	6.00	0.00
1.00	7040.93	3.93	9120.	62232.	6.00	6.00	0.00

RUN 1

TOP DAM 7037.0 feet

SPILLWAY 7029.6 feet

SPILLWAY WIDTH 107.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7029.60	7029.60	7037.00
STORAGE	4822.	4822.	7400.
OUTFLOW	0.	0.	13801.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7034.01	0.00	6260.	6237.	0.00	7.50	0.00
.35	7036.37	0.00	7149.	11991.	0.00	7.00	0.00
.50	7037.90	.90	7773.	21919.	2.50	6.50	0.00
.65	7038.74	1.74	8129.	33170.	3.50	6.50	0.00
.80	7039.49	2.49	8459.	45427.	4.50	6.00	0.00
1.00	7040.40	3.40	8873.	62595.	5.00	6.00	0.00

RUN 2

TOP	7037.0 feet
SPILLWAY	7029.6 feet
SPILLWAY WIDTH	200.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7029.60	7029.60	7040.00
STORAGE	4822.	4822.	8689.
OUTFLOW	0.	0.	13817.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7034.95	0.00	6605.	4745.	0.00	8.00	0.00
.35	7037.71	0.00	7691.	9266.	0.00	7.50	0.00
.50	7040.09	.09	8731.	14181.	1.00	7.50	0.00
.65	7041.22	1.22	9259.	24537.	3.00	7.00	0.00
.80	7042.18	2.18	9723.	37858.	4.00	6.50	0.00
1.00	7043.02	3.02	10142.	51902.	5.00	6.00	0.00

RUN 3

20

TOP	7040.0 feet
SPILLWAY	7029.6 feet
SPILLWAY WIDTH	107.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7029.60	7029.60	7040.00
STORAGE	4822.	4822.	8689.
OUTFLOW	0.	0.	46472.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7034.76	0.00	6531.	5009.	0.00	8.00	0.00
.35	7037.32	0.00	7532.	10704.	0.00	7.50	0.00
.50	7038.45	0.00	8003.	22403.	0.00	6.50	0.00
.65	7039.21	0.00	8337.	33359.	0.00	6.50	0.00
.80	7039.93	0.00	8657.	45212.	0.00	6.00	0.00
1.00	7040.84	.84	9077.	62267.	1.00	6.00	0.00

RUN 4

TOP 7040.0 feet

SPILLWAY 7029.6 feet

SPILLWAY WIDTH 125.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7029.60	7029.60	7040.00
STORAGE	4822.	4822.	8689.
OUTFLOW	0.	0.	47025.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7034.69	0.00	6507.	5101.	0.00	8.00	0.00
.35	7037.27	0.00	7510.	10668.	0.00	7.50	0.00
.50	7038.41	0.00	7987.	22380.	0.00	6.50	0.00
.65	7039.18	0.00	8322.	33345.	0.00	6.50	0.00
.80	7039.90	0.00	8643.	45231.	0.00	6.00	0.00
1.00	7040.81	.81	9063.	62291.	1.00	6.00	0.00

RUN 5

TOP	7040.0 feet
SPILLWAY	7029.6 feet
SPILLWAY WIDTH	130.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	7029.60	7029.60	7040.00
	STORAGE	4822.	4822.	8689.
	OUTFLOW	0.	0.	50345.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7034.37	0.00	6390.	5651.	0.00	7.50	0.00
.35	7036.88	0.00	7350.	10792.	0.00	7.50	0.00
.50	7038.20	0.00	7897.	22224.	0.00	6.50	0.00
.65	7038.99	0.00	8238.	33264.	0.00	6.50	0.00
.80	7039.72	0.00	8563.	45330.	0.00	6.00	0.00
1.00	7040.63	.63	8980.	62427.	1.00	6.00	0.00

RUN 6

TOP	7040.0 feet
SPILLWAY	7029.6 feet
SPILLWAY WIDTH	160.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7029.60	7029.60	7040.00
STORAGE	4822.	4822.	8689.
OUTFLOW	0.	0.	54772.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7034.01	0.00	6260.	6237.	0.00	7.50	0.00
.35	7036.37	0.00	7149.	11991.	0.00	7.00	0.00
.50	7037.90	0.00	7773.	21919.	0.00	6.50	0.00
.65	7038.74	0.00	8129.	33170.	0.00	6.50	0.00
.80	7039.49	0.00	8459.	45427.	0.00	6.00	0.00
1.00	7040.40	.40	8873.	62595.	.50	6.00	0.00

RUN 7

TOP	7040.0 feet
SPILLWAY	7029.6 feet
WIDTH	200.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7025.60	7025.60	7037.00
STORAGE	3718.	3718.	7400.
OUTFLOW	0.	0.	25919.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7030.37	0.00	5053.	6875.	0.00	7.00	0.00
.35	7032.87	0.00	5860.	12990.	0.00	7.00	0.00
.50	7034.99	0.00	6619.	19200.	0.00	7.00	0.00
.65	7036.90	0.00	7359.	25499.	0.00	6.50	0.00
.80	7038.22	1.22	7907.	38750.	2.00	6.50	0.00
1.00	7039.21	2.21	8333.	54081.	2.50	6.00	0.00

RUN 8

TOP	7037. 0 feet
SPILLWAY	7025.6 feet
SPILLWAY WIDTH	200.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7027.60	7027.60	7037.00
STORAGE	4251.	4251.	7400.
OUTFLOW	0.	0.	19536.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7032.21	0.00	5638.	6557.	0.00	7.00	0.00
.35	7034.64	0.00	6487.	12491.	0.00	7.00	0.00
.50	7036.71	0.00	7285.	18564.	0.00	7.00	0.00
.65	7038.10	1.10	7856.	30433.	2.00	6.50	0.00
.80	7038.83	1.83	8168.	40889.	3.00	6.50	0.00
1.00	7039.92	2.92	8655.	60010.	4.00	6.00	0.00

RUN 9

TOP	7037.0 feet
SPILLWAY	7027.6 feet
SPILLWAY WIDTH	200.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7028.30	7028.30	7037.00
STORAGE	4446.	4446.	7400.
OUTFLOW	0.	0.	17451.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7032.84	0.00	5851.	6443.	0.00	7.00	0.00
.35	7035.25	0.00	6715.	12316.	0.00	7.00	0.00
.50	7037.25	.25	7500.	19100.	1.00	7.00	0.00
.65	7038.36	1.36	7964.	31612.	2.50	6.50	0.00
.80	7039.02	2.02	8251.	41626.	3.00	6.00	0.00
1.00	7040.11	3.11	8737.	61085.	4.00	6.00	0.00

RUN 10

TOP	7037.0 feet
SPILLWAY	7028.3 feet
SPILLWAY WIDTH	200.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	7027.30	7027.30	7037.00
STORAGE	4168.	4168.	7400.
OUTFLOW	0.	0.	16466.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7032.31	0.00	5671.	5949.	0.00	7.50	0.00
.35	7034.93	0.00	6597.	11334.	0.00	7.00	0.00
.50	7037.19	.19	7476.	17567.	1.00	7.00	0.00
.65	7038.37	1.37	7972.	30230.	2.50	6.50	0.00
.80	7039.09	2.09	8283.	40794.	3.50	6.50	0.00
1.00	7040.16	3.16	8761.	59495.	4.50	6.00	0.00

RUN 11

TOP 7037.0 feet

SPILLWAY 7027.3 feet

SPILLWAY WIDTH 160.0 feet

SUMMARY OF DAM SAFETY ANALYSIS

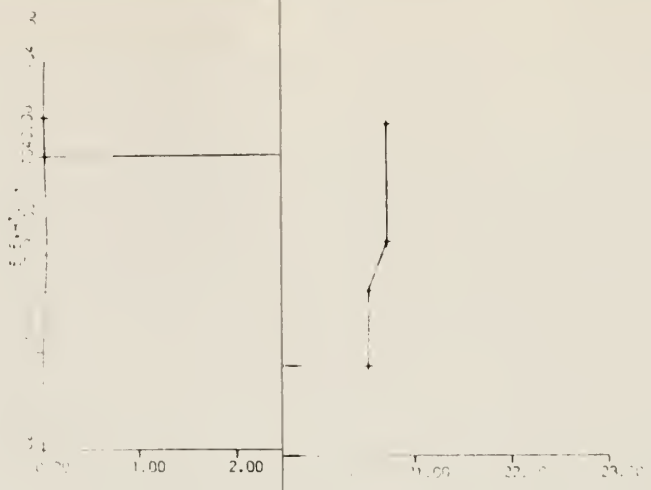
PLAN 1		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	7029.60	7029.60	7040.00
	STORAGE	4822.	4822.	8689.
	OUTFLOW	0.	0.	18183.

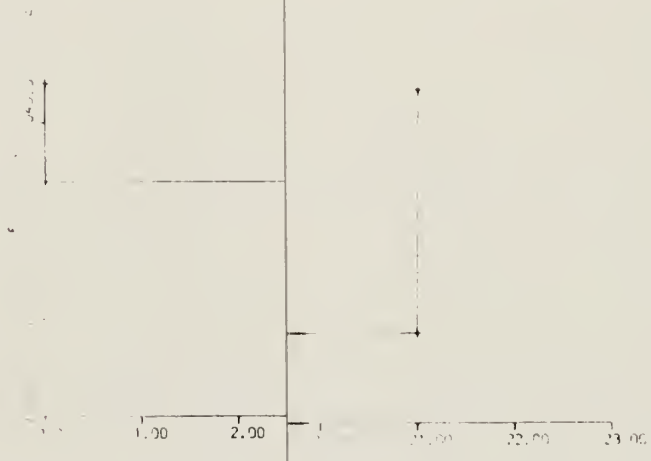
RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	7034.66	0.00	6497.	5222.	0.00	7.50	0.00
.35	7037.24	0.00	7496.	10346.	0.00	7.50	0.00
.50	7039.34	0.00	8393.	16065.	0.00	7.00	0.00
.65	7040.77	.77	9045.	24515.	2.00	7.00	0.00
.80	7041.78	1.78	9529.	38278.	3.00	6.50	0.00
1.00	7042.64	2.64	9951.	52901.	4.00	6.00	0.00

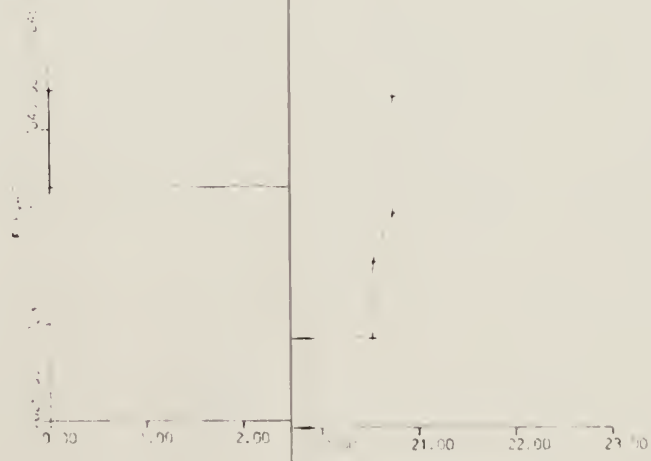
RUN 12

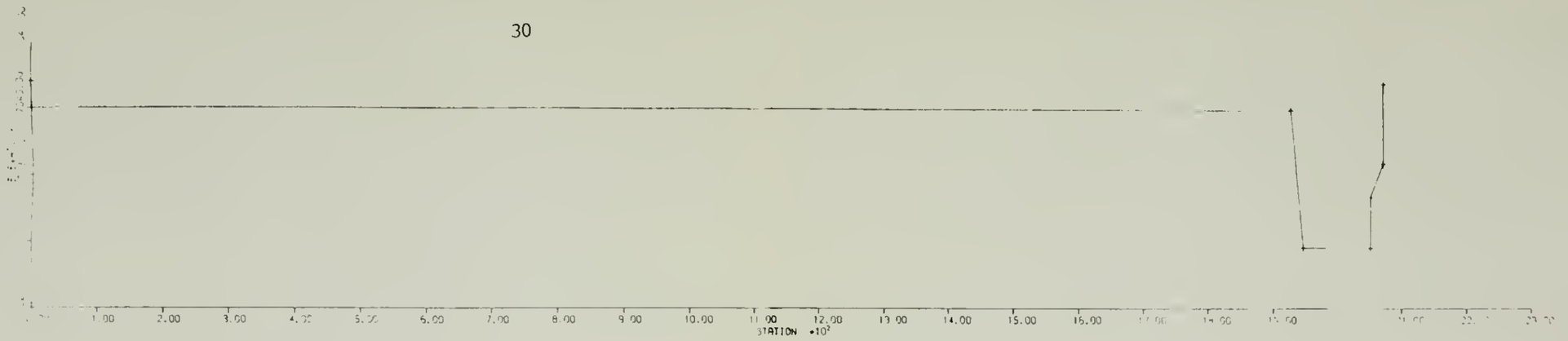
TOP DAM	7040.0 feet
SPILLWAY	7029.6 feet
SPILLWAY WIDTH	107.0 feet

Job No. 912-1028

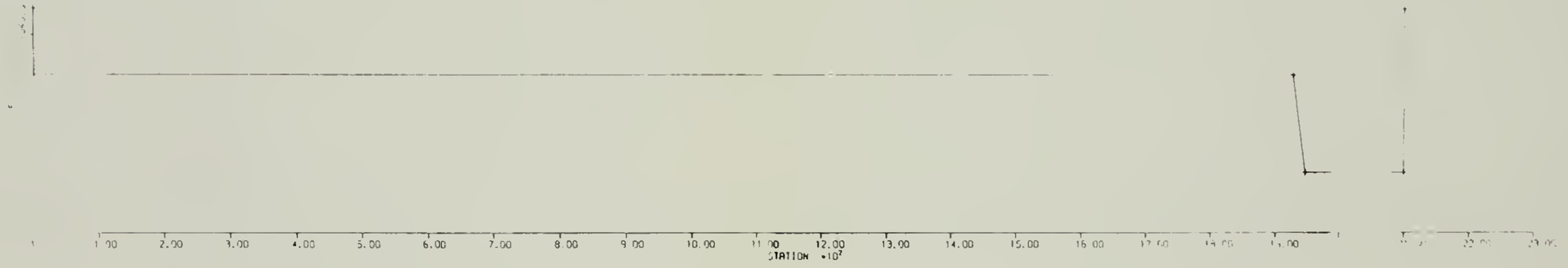




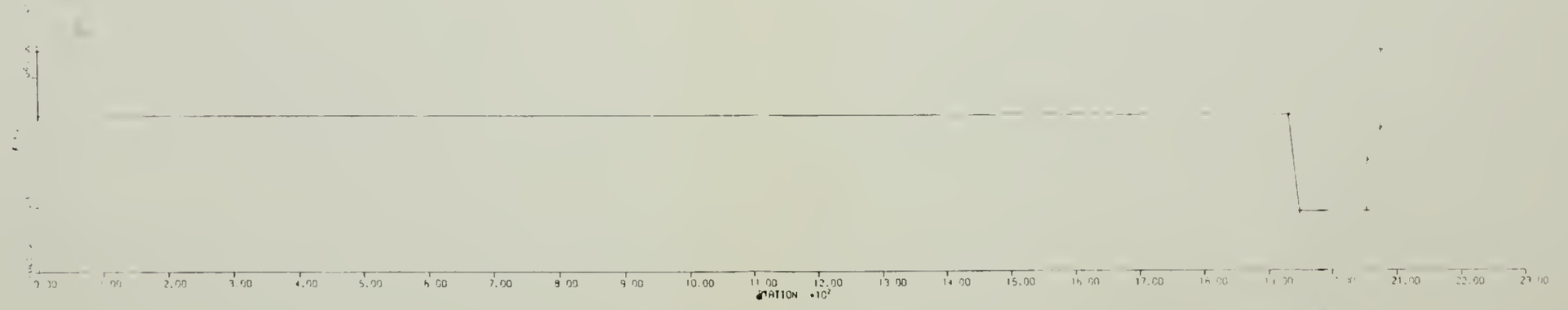




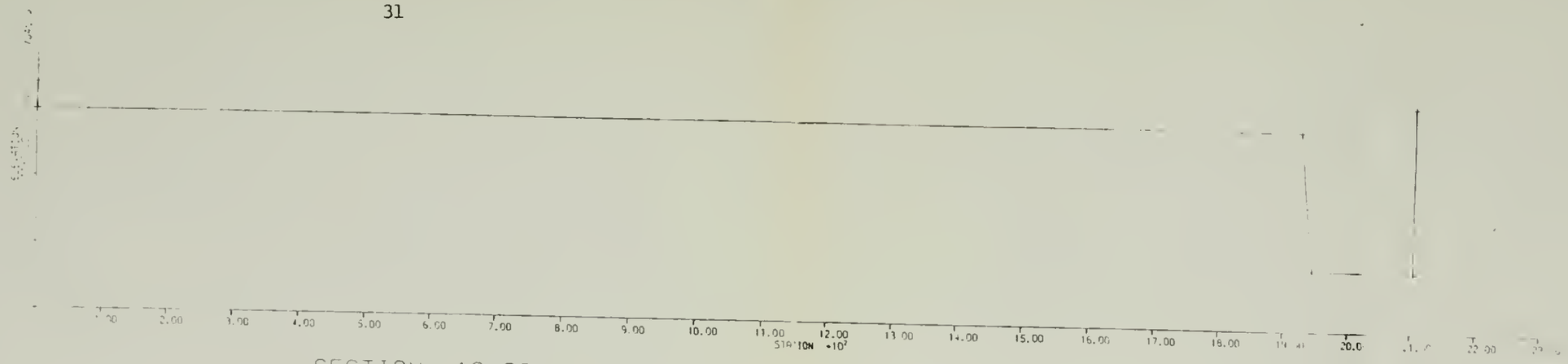
SECTION 13.03



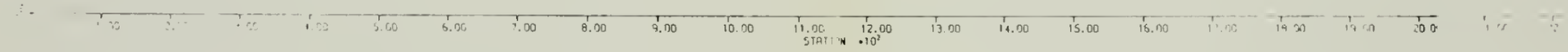
SECTION 13.02



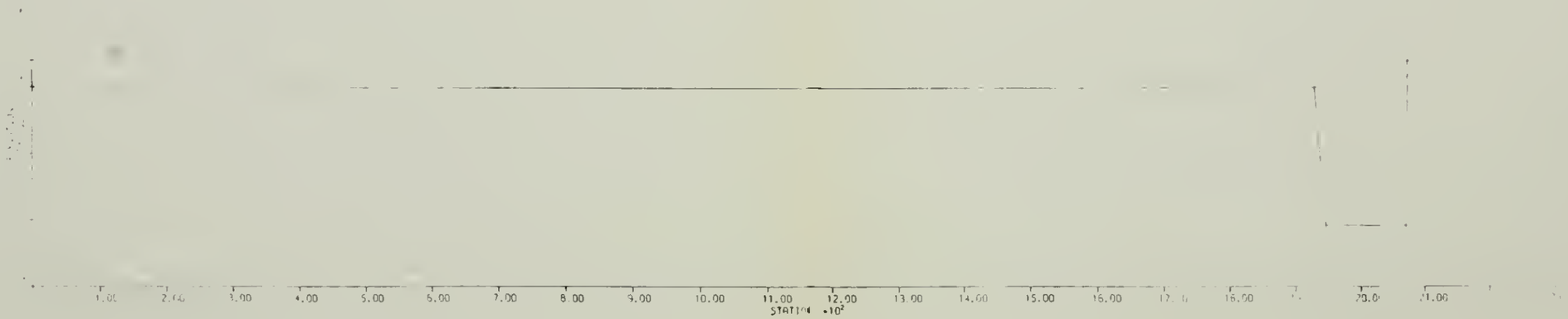
SECTION 13.01



SECTION 13.06

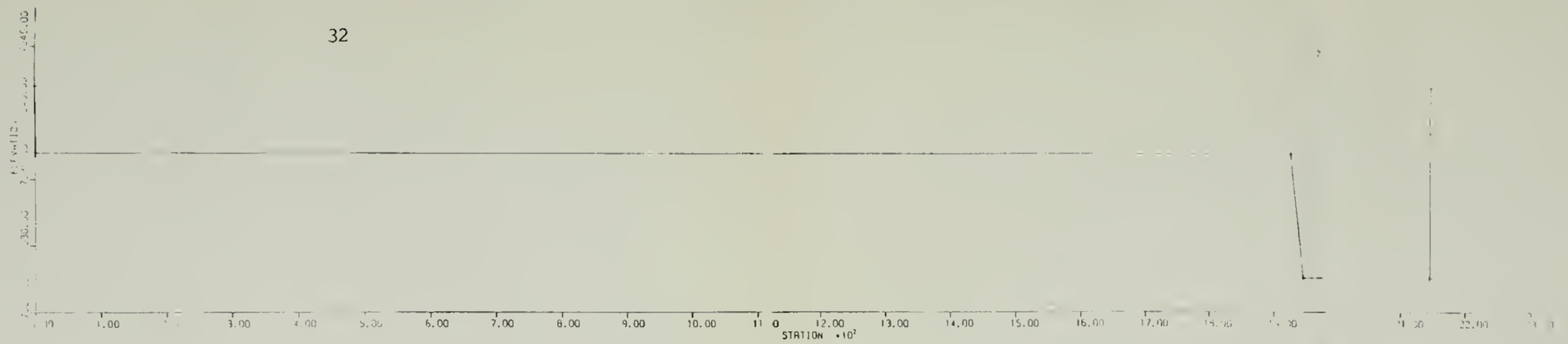


SECTION 13.05

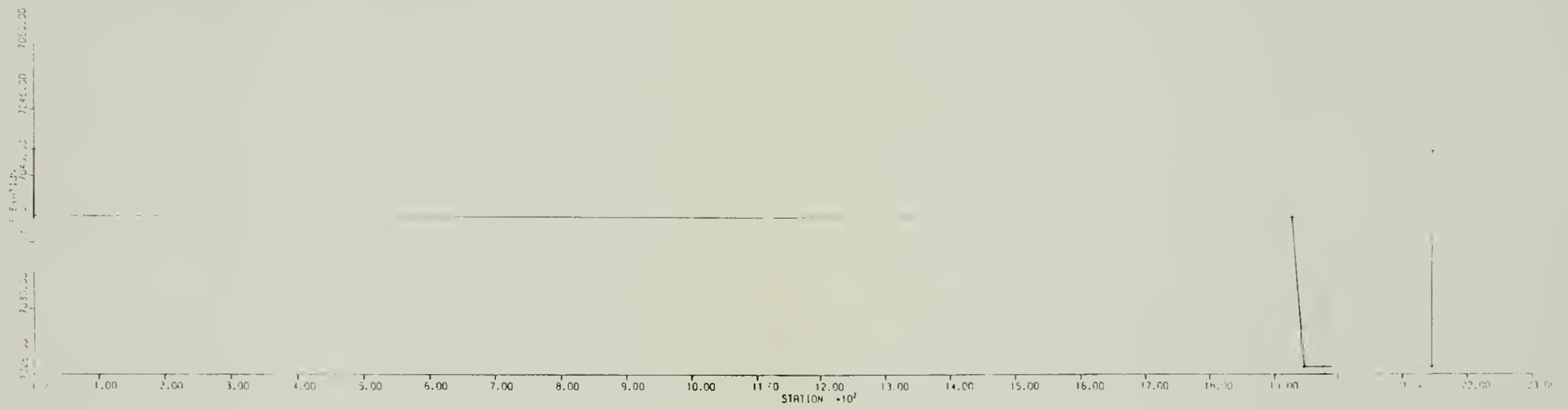


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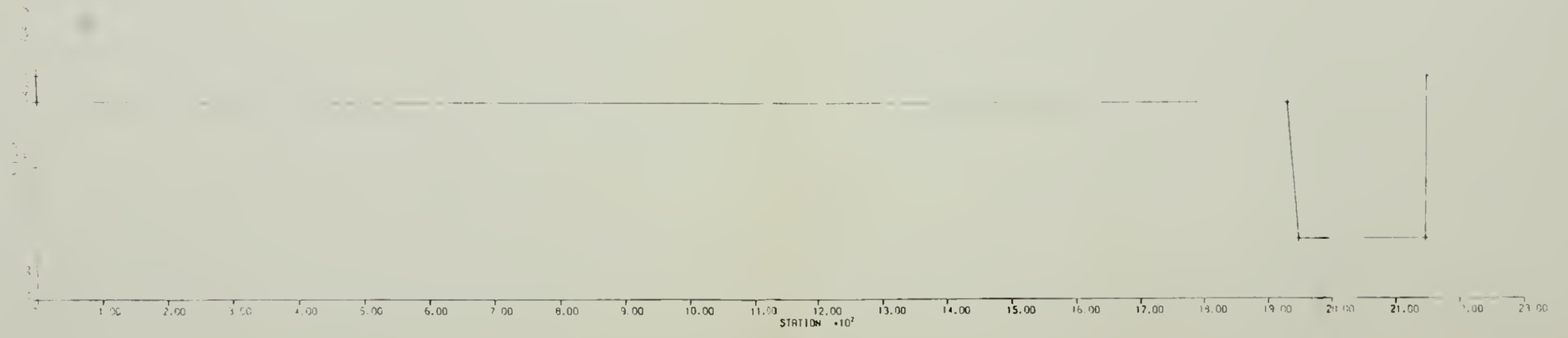
Job No. 912-1028



SECTION 13.09

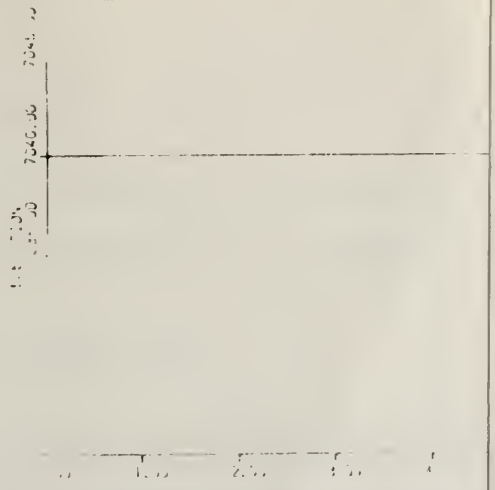


SECTION 13.08

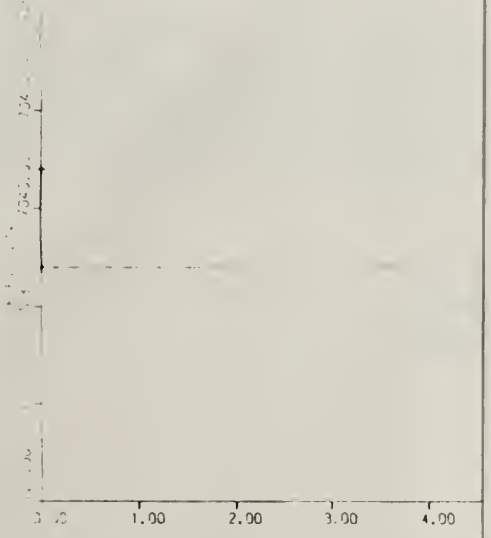


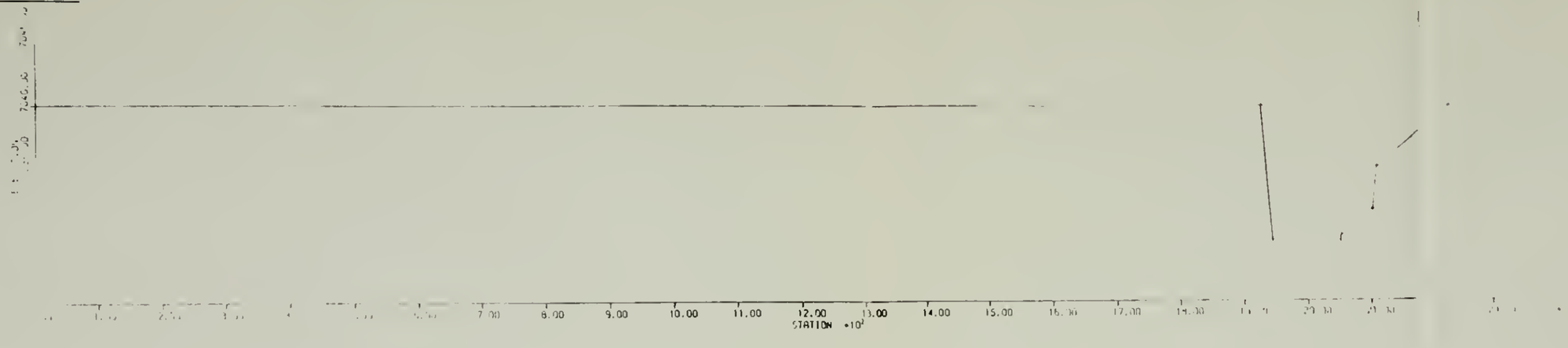
SECTION 13.07

ob No. 912-1028

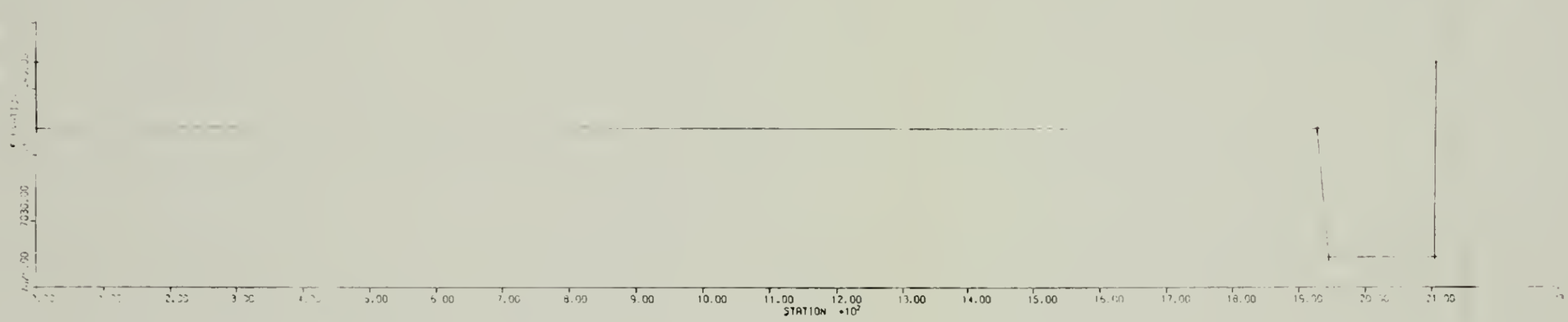




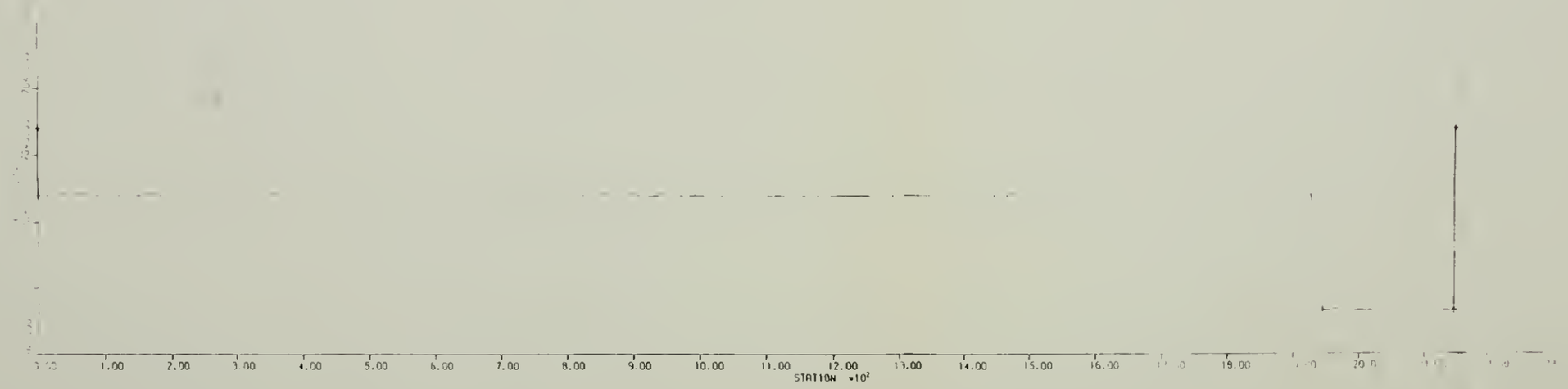




SECTION 13.12



SECTION 13.11



SECTION 13.10